Volume II of V

U.S. DEEPWATER PORT STUDY

COMMODITY STUDIES AND PROJECTIONS

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13. ABSTRACT

This report provides an overall appraisal of deep port needs for the United States by means of identification of the factors critical to U. S. deepwater port decision; development of criteria appropriate to the evaluation of engineering, economic and environmental aspects of deep port needs and policies, analysis of the development options available at this time and the critical issues surrounding each and the identification of critical issues which need further analysis. The study emphasizes port requirements for bulk commodities.

Volume I contains the Summary Report

Volume II contains Commodity Studies and Projections

Volume III contains Physical Coast and Port Characteristics, and Selected Deepwater Port Alternatives

Volume IV contains The Environmental and Ecological Aspects of Deepwater Ports

Volume V contains Transport of Bulk Commodities and Benefit-Cost Relationships

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ANNEX A-1. LONG-TERM PROJECTIONS OF ECONOMIC AGGREGATES FOR THE UNITED STATES, EUROPE, AND JAPAN

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INTRODUCTION

Long-term projections can never be accepted without question. The validity of such projections depends not only on uncertain future effects of current policies, but also on future policies which are often not foreseeable. In 1960, for instance, it would have been difficult to base projections for the decade on the economic effects of a war resulting from the then current U.S. national policy of Communist containment in Asia; and only a few years ago, it would have required extraordinary foresight to translate a vague concern about environmental problems in the United States into policies which might have significant economic impacts throughout the remainder of this century. The increase in national concern about the environment will undoubtedly result in changing production costs (as measures to protect the environment are incorporated in production processes) and the structure of production (as old products are altered and new products are introduced to meet demands influenced by environmental considerations). Nevertheless, as imperfect as long-term projections may be, they are necessary if any attempt is to be made to determine future needs or to identify and evaluate projects to meet the needs.

To some degree, the future is less uncertain than it might appear. It is known that all persons who will be 28 years or older in 2000 will have already been born by the end of 1972, and the entire labor force which will be available in 1980 is now alive. Further, because of the long lead time required to introduce new technology, most major technological changes during the next generation will be based on the development of existing technology.

In projecting economic aggregates to 2000, past trends have carefully been examined to determine how the past and present might be related to the future. This relationship, modified by judgmental evaluations of the possible effects of future policies and events, serves as a basis for the following projections.

I. PROJECTIONS OF U.S. ECONOMIC AGGREGATES

A variety of techniques were employed in projecting U.S. aggregates. However, in most instances, data and projections provided by other studies served as fundamental building blocks. In particular, data and projections provided by the U.S. Bureau of the Census, the Bureau of Labor Statistics and the National Planning Association were used throughout this study.

Projections of U.S. Population

The Series C projection[1/] by the Bureau of the Census (Current Population Report, Series P-25, No. 442, March 20, 1970) has been selected as most likely to represent the demographic changes that will take place between 1970 and 2000. The Series C projection results in a population of 232 million in 1980, 266 million in 1990, and 301 million in 2000 (table 1).

Fertility rates in the United States during the late 1960's were at their lowest level since World War II. From a peak general fertility rate[2/] of 123.0 in 1957, the rate fell steadily to 86.5 in 1968. The 1969 rate was 86.6 and the 1970 rate was 87.6, indicating that the decline halted, at least temporarily. These

1/ More recent census estimates have become available since this analysis was made, but they do not significantly alter the analysis or the estimates.
2/ Annual births per 1,000 women aged 15 to 44.

Table 1. Total Population of the United States,[a] 1965 and 1970 (Actual), and 1980, 1990 and 2000 (Estimated)

(In thousands)

Bureau of the Census series	1965	1970	1980	1990	2000
B.............			236.8	277.3	320.8
C.............	194.6	205.4	232.4	266.3	300.8
D.............			227.5	254.7	280.7

a/ Includes armed forces abroad. Population estimated as of 7/1.

Source: U.S. Department of Commerce, Current Population Report, Bureau of the Census Series P-25, No. 442 (March 20, 1970) and No. 448 (August 6, 1970).

rates were not much above those of the depression years of the 1930's, when a low of 75.8 was reached in 1936. The ultimate completed fertility rate[1] in 1968 was 2,460, compared to 3,655 in 1960.

The Census Series C projection, which incorporates the 1969 actual fertility rates, indicates an increase in the general fertility rate to 97.3 by 1980, followed by a decrease to 92.2 in 2000. This would mean that general fertility rates would not surpass the 1965 level throughout the projection period, although they would average above the 1966-70 level. The ultimate completed fertility rate in the medium projection would increase steadily to 2,775 in 2000, approximately the average of the rate that prevailed from 1965 to 1969. Included in the projected fertility rates is the assumption that, on the average, women will bear children at a later age than has occurred in recent years. The

1/ Number of births per 1,000 women at the end of childbearing age.

proportion of children born to women aged 30 and older is expected to increase from 25 percent in 1968 to 31 percent in 2000.

There are three components of population change used in the Bureau of the Census projections: fertility rates, mortality rates and net immigration. Mortality rates are the same in all Census projections and change little over the years. Immigration was assumed to be 400,000 per year in all projections for all years. Fertility rates are the most important variable, and minor changes have a considerable effect on population levels for many years.

Should the ultimate fertility rate remain at about the 1968 level between 1970 and 2000, the total population of the United States would approximate the Series D projection of the Bureau of the Census. These projections result in a population of 281 million in 2000.

If fertility rates increase to the level of the mid-1960's by 2000, the Series B projection of the Bureau of the Census is more likely to be attained, resulting in a population of 321 million in 2000.

Because it is not clear yet how present levels in fertility rates will finally affect family size and consequently population size, we have chosen the Series C projection. High fertility rates for a few years may mean that families are being completed as soon as possible; lower fertility rates may mean that children are being postponed. Should the current lower fertility rates result more from postponement than from an overall reduction in family size, the fertility rate would need only return to the level of the early and mid-1960's for the medium projection of population to be too low.

The decision to have a large or a small family is influenced by a number of interrelated variables: social and religious attitudes, economic conditions, family income levels, the knowledge and availability

of birth control methods, and simply "fashion." Close correlation between trends in family size and these variables is difficult to discern. Affluence, for example, can encourage families to have more children; on the other hand, if interesting jobs are readily available to women, they may prefer to work rather than have a large family.

Although there was a downward trend in family size during the 1930's, there is no indication that families living continually in poverty have fewer children than the affluent. In fact, because of ignorance and the unavailability of artificial contraception methods, poor families have tended to be large families. With the increasing knowledge and availability of birth control methods and the changing social and religious attitudes towards artificial birth control, more and more parents can decide on the timing and number of their children. Despite these influences, there may well be an upward trend in the birth rate for a number of years.

Projections of U.S. Gross National Product

Gross national product (GNP) (in 1958 dollars) is projected to be $1,173.6 billion in 1980, $1,711.3 billion in 1990, and $2,583.2 billion in 2000 (table 2). These projections are based on consideration of the following variables:

1. Employment (civilian and armed forces)
2. Productivity (GNP per man-hour)
3. Average hours worked per week per employed person.

Employment

The labor force was projected on the basis of labor force participation rates1/ assumed for the male

1/ Proportion of the population in the labor force, i.e., those working or available for work (unemployed).

Table 2. Gross National Product and Growth Rate,[a] 1968 (Actual) and 1980, 1990 and 2000 (Estimated)

(In 1958 dollars)

Item	1968	1980	1990	2000
GNP per man-hour.	4.52	6.31	8.48	11.29
Growth rate.....		2.9	2.9	2.9
GNP per employee.	8,901	12,112	15,791	20,544
Growth rate.....		2.6	2.7	2.7
Weekly man-hours per employee....	37.9[b]	36.6	35.8	35.0
Growth rate.....		-0.3	-0.2	-0.2
Total man-hours. (billions)......	156.6[b]	184.2	201.8	228.8
Employment[c] (thousands).....	79,455	96,899	108,374	125,740
Growth rate.....		1.7	1.1	1.5
GNP (billions)...	707.2	1,173.6	1,711.3	2,583.2
Growth rate.....		4.3	3.8	4.2

Note: GNP growth rate 1968-2000 = 4.1 percent.
a/ Annual growth rate over previous period.
b/ Estimate by National Planning Association for all employees.
c/ Civilian employment and armed forces.

Source: 1968 -- U.S. Office of the President, Economic Report of the President (Washington, D.C.: Government Printing Office, 1971); and National Planning Association, Center for Economic Projections, Economic Projections to 1980: Growth Patterns for the Coming Decade, National Economic Projections Series, Report 70-N-1, March 1970.

and female population in various age groups. For 1980, labor force participation rates projected by the Bureau of Labor Statistics were applied to the Bureau of the Census Series C population projections of those aged 16 and over.1/ Participation rates for 1990 and 2000 were obtained by extrapolating the trend indicated by the Bureau of Labor Statistics for the 1968-85 period. It is projected that the total labor force (civilian and armed forces) will be 100.8 million in 1980, 112.8 million in 1990, and 130.9 million in 2000 (table 3).

The most significant change in the composition of the labor force indicated by the Bureau of Labor Statistics' projections is the increased participation rate of women, particularly those aged 20 and over. From 1968 to 1980, the proportion of women aged 20 to 64 in the labor force was projected to increase from 47.6 percent to 50.3 percent; the male participation rate during this period was expected to remain more or less constant.

The projections of the civilian labor force were obtained by subtracting the estimated armed forces population and the estimated institutional population2/ over 16 years of age from the total labor force.3/

Total civilian employment was estimated by assuming an unemployment rate of 4 percent of the civilian labor force for 1980, 1990 and 2000. It was assumed that a long period of unemployment above this level would be politically untenable and that the government would take measures so that the long-run average was not above 4 percent.

1/ The Bureau of Labor Statistics published projected participation rates for 1975, 1980 and 1985 in BLS Special Report 119.

2/ Those in prison, mental hospitals, etc.

3/ The estimate of armed forces and institutional population of the Bureau of Labor Statistics was used for 1980. Armed forces strength was assumed to be 2 million in 1990 and 2000; the institutional population was assumed to be 1.5 percent of the population over 16 (the same proportion as 1980).

Table 3. Total Labor Force, Civilian Employment and Armed Forces, 1968-70 (Actual) and 1980, 1900, and 2000 (Estimated)

(In thousands)

Labor force	1968	1969	1970	1980	1990	2000
Population 16 years and over..........	137,668	139,996	142,365	167,130 a/	185,960 a/	213,019 a/
Labor force participation rate.....	59.8	60.2	60.1	60.3	60.7	61.4
Number in labor force.............	82,272	84,239	85,903	100,826 b/	112,806 b/	130,896 b/
Armed forces.......	3,535	3,506	3,188	2,650 c/	2,000 c/	2,000 c/
Institutional population........	2,106	2,155	2,183	2,500 d/	2,790 d/	3,200 d/
Noninstitutional population........	135,562	137,841	140,182	161,980	183,170	209,819
Civilian noninstitutional labor force.............	78,737	80,733	82,715	98,176	110,806	128,896
Percent unemployed.	3.6	3.5	4.9	4.0	4.0	4.0
Civilian employment.............	75,920	77,902	78,627	94,249	106,374	123,740
Civilian employment and armed forces..	79,455	81,408	81,815	96,899	108,374	125,740

a/ Bureau of the Census Series C projection (Current Population Report, Series P-25, No. 448, August 6, 1970). 1968-70 data taken from U.S. Department of Labor, Bureau of Labor Statistics, Special Report 119, and Employment and Earnings, November 1970.

continued--

Table 3. Total Labor Force, Civilian Employment and Armed Forces, 1968-70 (Actual) and 1980, 1990, and 2000 (Estimated)
continued--

b/ Based on Series C projection of Bureau of the Census (Current Population Report, Series P-25, No. 448, August 6, 1970) and participation rates from Bureau of Labor Statistics (BLS Special Report 119) calculated by age groups. Participation rates for 1990 and 2000 extrapolated from BLS 1968-85 trend.

c/ Estimate used by BLS (Special Report 119) for 1980. Assumed 2 million in 1990 and 2000.

d/ 1.5 percent of population over age 16 in 1980 (BLS estimate, Special Report 119). 1.5 percent also used for 1990 and 2000.

Productivity

GNP per man-hour is projected to increase at an average annual rate of 2.9 percent between 1968 and 2000. This projection assumes that the decline in productivity growth during the recession which started in the last half of 1968 will not influence the long-term productivity trend. Since World War II, losses in productivity due to recessions have always been recovered as the economy recovers. For this reason, 1968, the last year of trend growth prior to the recession, was selected as the base from which to estimate future GNP per employed person.

It is projected that GNP per man-hour will be \$6.37 in 1980, \$8.48 in 1990 and \$11.29 in 2000 (1958 dollars). This compares to \$4.52 per man-hour in 1968 (table 2).

Average Weekly Man-Hours

Between 1948 and 1968, average man-hours actually worked per employed person per week declined from 42.2 to 37.9 hours (0.5 percent annually).[1] While it is assumed that weekly man-hours will continue to decline, the rate of decline is projected to decrease as the weekly hour base becomes smaller. Between 1968 and 1980, the rate of decline is projected to be 0.3 percent, resulting in an average of 36.6 hours per week per employed person in 1980. From 1980 to 2000, the rate of decline is projected to be 0.2 percent. Average weekly hours worked are projected to be 35.8 and 35.0 hours in 1990 and 2000, respectively (table 2).

Comparisons With Other Studies

Although a comparison of projections is far from an adequate test of their validity, it does serve to

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1/ Based on a series developed by the National Planning Association in Revised National Economic Projections

highlight major deviations which can stimulate a reconsideration of assumptions and approaches. For this reason, projections made by others have been reviewed. In particular, the projections made during the course of this study were compared with those of the U.S. Department of Commerce, Office of Business Economics (OBE),1/ and with projections of the National Planning Association (NPA).2/ Projections by OBE extend to 2020, and those of NPA, to 1980. Comparisons were also made with informal projections to 2000 prepared by the Economic Research Service (ERS) of the U.S. Department of Agriculture.3/ With only minor differences, these projections generally agree with the projections presented here of probable future rates and magnitudes of economic growth, and the future structure of the economy.

Both the OBE and ERS projections predict rates of growth in GNP of approximately 4.1 percent between 1968 and 2000, the rate projected here. Although NPA has not made projections to 2000, its projections to 1980 compare closely with those of ERS, OBE, and Robert R. Nathan Associates (RRNA). A summary of the GNP projections by the four research organizations is shown in table 4.

Projections of GNP Components

Projections of GNP components are based on projections made by the NPA. Consumption, investment and government shares of GNP projected by NPA for 1980 were

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to 1980, by Ahmad Al-Samarrie and Graham C. Scott, National Economic Projection Series, Report 71-N-2, November 1971.

1/ U.S. Department of Commerce, Office of Business Economics, 1971.

2/ National Planning Association, Revised National Economic Projections to 1980, by Ahmad Al-Samarrie and Graham C. Scott, National Economic Projection Series, Report 71-N-2, November 1971.

3/ U.S. Department of Agriculture, Economic Research Service, Discussion Materials: Informal Projections, 1 October 1970.

Table 4. Comparisons of GNP Projections, 1968 (Actual) and 1980, 1990, and 2000 (Estimated)

(In billions of 1958 dollars)

Source	1968	1980	1990	2000
RRNA..........	707.2	1,173.6	1,711.3	2,583.2
ERS...........	707.2	1,120.0	1,675.0	2,583.0
OBE...........	707.2	1,153.9	--	2,505.9
NPA...........	707.2	1,148.6	--	--

accepted and applied to RRNA projections of GNP. For 1990 and 2000, it was assumed that the direction of changes in shares projected by NPA between 1968 and 1980 would not change. However, it was estimated that the rate of change would tend to decline (tables 5 and 6). In particular, the change in shares between 1980 and 2000 was projected to be the same as the change between 1968 and 1980. For example, the share of gross domestic private investment, as a percent of GNP, was 14.95 percent in 1968 and was projected to be 15.99 percent in 1980 -- an increase of 7.0 percent over the 12 year period. It was therefore assumed that for the 20 year period, 1980 to 2000, the share would increase by another 7.0 percent to 17.03 percent, implying a declining rate of change. The implied share of this component for 1990 is 16.51 percent.

The projections indicate that by 2000, personal consumption expenditures will account for 66.73 percent of GNP, as compared to 63.95 percent in 1968 (table 5). This shift is anticipated as a result of continued increases in the consumption of durable goods and services. Nondurables are projected to decline as a share of total consumption. This projection is plausible in terms of both the anticipated increase in per capita incomes, the effects of such increases on durable goods consumption, and the trend in increased consumption of services which has been so pronounced since World War II.

The projected decline in the share of GNP allocated to Government is offset by the large absolute

Table 5. GNP by Component, 1968 (Actual) and 1980, 1990, 2000 (Estimated)

Component	Gross national product				Percentage share of total GNP			
	1968	1980	1990	2000	1968	1980	1990	2000
	------- bil. of 1958 dol. ---							
Total GNP..............	707.2	1,173.6	1,711.3	2,583.2	100.00	100.00	100.00	100.00
Personal consumption expenditures..........	452.3	766.8	1,130.1	1,723.8	63.95[a/]	65.34	66.04	66.73
Durable...............	81.4	149.3	228.1	360.1	11.51	12.72	13.33	13.94
Nondurable............	196.5	313.4	447.5	661.8	27.79	26.70	26.15	25.62
Services..............	174.4	304.1	454.2	701.9	24.66	25.91	26.54	27.17
Gross domestic private investment...........	105.7	187.7	282.5	439.9	14.95	15.99	16.51	17.03
Fixed investment......	98.8	179.1	272.3	427.8	13.97	15.26	15.91	16.56
Nonresidential........	74.5	139.3	213.6	337.9	10.66	11.87	12.48	13.08
Structures...........	22.7	38.7	57.3	87.6	3.21	3.30	3.35	3.39
Producers durable equipment...........	52.7	100.6	156.2	250.3	7.45	8.57	9.13	9.69
Residential...........	23.3	39.8	58.9	90.2	3.29	3.39	3.44	3.49
Changes in inventories.	6.9	8.4	10.1	11.9	0.98	0.72	0.59	0.46
Net exports of goods and services..........	0.9	7.7	15.7	30.7	0.13	0.66	0.92	1.19
Exports...............	45.7	96.0	154.7	255.7	6.46	8.18	9.04	9.90
Imports...............	44.8	88.3	139.0	225.0	6.33	7.52	8.12	8.71
Government purchases of goods and services....	148.3	211.4	282.9	388.8	20.97	18.01	16.53	15.05

a/ Actual percent is 63.9564.

Source: 1968 -- U.S. Office of the President, Economic Report of the President, (Washington, D.C.: Government Printing Office, 1971). 1980 -- Percentage shares from National Planning Association, An Econometric Model for Long-Range Projections of the United States Economy, by Ahmad Al-Samarrie and Graham C. Scott, National Economic Projection Series, Report 71-N-1, 1971; all others estimated by RRNA.

Table 6. Projections of GNP by Component Annual Growth Rates, 1968 (Actual) and 1980, 1990 and 2000 (Estimated)

(In 1958 dollars)

Component	1968-1980	1968-1990	1968-2000	1980-1990	1980-2000	1990 2000
Total GNP...............	4.3	4.1	4.1	3.8	4.0	4.2
Personal consumption expenditures..........	4.5	4.2	4.3	4.0	4.1	4.3
Durable................	5.2	4.8	4.8	4.3	4.5	4.7
Nondurable............	4.0	3.8	3.9	3.6	3.8	4.0
Services..............	4.7	4.4	4.4	4.1	4.3	4.4
Gross domestic private investment....	4.9	4.6	4.6	4.2	4.4	4.5
Fixed investment......	5.1	4.7	4.7	4.3	4.4	4.6
Nonresidential.......	5.2	4.8	4.8	4.4	4.5	4.7
Structures..........	4.5	4.3	4.3	4.0	4.2	4.3
Producers durable equipment..........	5.5	5.1	5.0	4.5	4.7	4.8
Residential..........	4.6	4.3	4.3	4.0	4.2	4.4
Net exports of goods and services..........	19.6	13.9	11.7	4.9	7.2	4.6
Exports...............	6.4	5.7	5.5	4.9	5.0	5.2
Imports...............	5.8	5.3	5.2	4.6	4.8	4.9
Changes in inventories.	2.0	1.7	1.7	1.9	1.8	1.7

increases which will occur in Government expenditures. Between 1968 and 2000, it is projected that Government purchases of goods and services will increase from $148.3 billion to $388.8 billion (1958 dollars), an increase of more than 160 percent (table 5).

Projections of State Economic Aggregates

There are serious difficulties in projecting state aggregates in the United States. Because state boundaries do not serve as constraints on the movements of goods or persons, it is difficult to determine with precision the value of goods and services produced in a given state. Further, future migratory patterns, influencing population and production, are not always foreseeable at state levels.

Projections of State Populations

The NPA study projects state populations to 1980.[1/] State percentage shares of national population implied by the NPA projections were applied to the projections of total population for 1980 used in this report (table 7).

For 1990 and 2000, projections of state percentage shares of national population were made by extrapolating historical trends. These shares were then applied to the RRNA national population projections for 1990 and 2000.

Projections of State Gross Product Originating

The NPA provides the only estimates and projections (to 1975) of national and state gross product

1/ National Planning Association, Center for Economic Projections, State Economic and Demographic Projections to 1975 and 1980, Regional Economic Projections Series, Report 70-R-1, April 1970.

Table 7. Total Residential Population by State (July 1)
(In thousands)

State	1968	1980	1990	2000
United States.....	199,846	232,412	266,319	300,789
Maine.............	978	1,069	1,332	1,203
New Hampshire.....	703	837	1,065	1,203
Vermont...........	429	488	533	602
Massachusetts.....	5,438	5,880	6,658	7,219
Rhode Island......	908	976	1,065	1,203
Connecticut.......	2,961	3,626	4,261	5,113
Total............	11,417	12,876	14,914	16,543
New York..........	18,186	20,638	23,436	26,169
New Jersey........	7,070	8,530	9,854	11,129
Pennsylvania......	11,750	12,597	14,381	15,942
Delaware..........	533	674	799	902
Maryland..........	3,716	4,671	5,327	6,016
District of Columbia.........	802	906	1,065	1,203
Total............	42,057	48,016	54,862	61,361
Ohio..............	10,610	12,202	13,849	15,340
Indiana...........	5,065	5,810	6,658	7,520
Illinois..........	10,958	12,388	13,849	15,641
Michigan..........	8,673	9,877	11,452	12,934
Wisconsin.........	4,211	4,695	5,592	6,317
Total............	39,517	44,972	51,400	57,752
Virginia..........	4,604	5,438	6,125	6,918
West Virginia.....	1,819	1,883	2,131	2,406
Kentucky..........	3,224	3,463	3,995	4,512
Tennessee.........	3,952	4,323	5,060	5,715
North Carolina....	5,131	5,810	6,658	7,520
South Carolina....	2,669	3,091	3,462	3,910
Georgia...........	4,579	5,415	6,125	6,918
Florida...........	6,210	8,158	9,321	10,828
Alabama...........	3,522	3,905	4,261	4,813
Mississippi.......	2,349	2,533	2,930	3,309
Louisiana.........	3,710	4,439	4,794	5,414
Arkansas..........	1,983	2,185	2,397	2,707
Total............	43,752	50,643	57,259	64,970

continued--

Table 7. Total Residential Population by State (July 1) continued--

(In thousands)

State	1968	1980	1990	2000
Minnesota.........	3,663	4,090	5,060	5,715
Iowa..............	2,775	2,859	3,729	4,211
Missouri..........	4,610	5,136	6,125	6,918
North Dakota......	624	651	799	902
South Dakota......	665	697	799	902
Nebraska..........	1,453	1,557	1,864	2,106
Kansas............	2,291	2,580	2,930	3,309
Total............	16,081	17,570	21,306	24,063
Oklahoma..........	2,542	2,859	3,196	3,609
Texas.............	11,013	13,061	14,914	17,145
Arizona...........	1,667	2,208	2,663	3,309
New Mexico........	994	1,162	1,331	1,504
Total............	16,216	19,290	22,104	25,567
Montana...........	696	767	799	902
Idaho.............	709	790	799	902
Wyoming...........	322	349	533	602
Utah..............	1,031	1,255	1,332	1,504
Colorado..........	2,067	2,510	2,929	3,309
Total............	4,825	5,671	6,392	7,219
Washington........	3,296	3,928	4,527	5,114
Oregon............	2,004	2,347	2,663	3,008
California........	19,179	25,193	28,762	32,786
Nevada............	449	627	799	902
Alaska............	276	349	266	301
Hawaii............	775	930	1,065	1,203
Total............	25,979	33,374	38,082	43,314

Source: 1968 -- U.S. Department of Commerce, Current Population Report, Bureau of the Census Series P-25, No. 430, August 29, 1969. 1980-2000 -- RRNA projections.

originating (GPO).[1/] National GPO is basically the same as GNP. As with population, the shares of national GPO which could be attributed to individual states were projected by extrapolating to 1980, 1990 and 2000 the long-term trend in shares projected by NPA. These projected shares of national GPO were then applied to RRNA projections of GNP in 1980, 1990, and 2000 to obtain estimates of individual state GPO in those years (table 8).

Three sectors were considered for each state: agriculture, manufacturing and all other. Because NPA also provides estimates and projections (through 1975) for these sectors, it was possible, using each sector's share of state GPO, to make projections for the sectors by extrapolating sector shares to target years.

1/ National Planning Association, Center for Economic Projections, Economic Projections to 1980: Growth Patterns for the Coming Decade, National Economic Projection Series, Report 70-N-1, March 1970.

Table 8. Gross Product Originating, by States
(In billions 1958 dollars)

State	NPA estimate 1962	RRNA projections		
		1980	1990	2000
United States..	524.4	1,173.6	1,711.3	2,583.2
Agriculture...	21.9	29.3	34.2	38.7
Manufacturing.	153.2	362.6	521.9	775.0
All other.....	349.3	781.6	1,155.1	1,769.5
Maine..........	2.3	4.7	6.7	10.1
Agriculture...	0.1	0.1	0.2	0.2
Manufacturing.	0.8	1.7	2.4	3.9
All other.....	1.4	2.9	4.1	6.0
New Hampshire..	1.7	3.8	5.5	8.3
Agriculture...	0.0	0.0	0.0	0.1
Manufacturing.	0.7	1.6	2.3	3.5
All other.....	1.0	2.2	3.2	4.7
Vermont........	0.9	2.2	3.3	4.9
Agriculture...	0.0	0.1	0.1	0.1
Manufacturing.	0.3	0.7	1.0	1.6
All other.....	0.6	1.5	2.2	3.2
Massachusetts..	16.8	34.5	50.0	74.9
Agriculture...	0.1	0.1	0.1	0.1
Manufacturing.	5.9	12.8	18.5	27.3
All other.....	10.8	21.6	31.4	47.5
Rhode Island...	2.5	5.5	8.0	12.1
Agriculture...	0.0	0.0	0.0	0.0
Manufacturing.	0.9	2.1	3.1	4.7
All other.....	1.5	3.4	4.9	7.4
Connecticut....	9.1	20.0	29.1	43.9
Agriculture...	0.1	0.1	0.1	0.1
Manufacturing.	3.9	8.4	11.6	18.4
All other.....	5.0	11.5	17.4	25.4
New York.......	62.1	124.4	179.7	268.7
Agriculture...	0.5	0.6	0.7	0.8
Manufacturing.	17.0	34.8	50.3	72.4
All other.....	44.6	88.9	128.7	195.5

continued--

Table 8. Gross Product Originating, by States continued--

(In billions 1958 dollars)

State	NPA estimate 1962	RRNA projections		
		1980	1990	2000
New Jersey.....	20.0	46.4	67.6	102.0
Agriculture....	0.2	0.2	0.2	0.2
Manufacturing.	7.7	17.6	25.7	39.0
All other......	12.0	28.6	41.7	62.8
Pennsylvania...	32.6	66.3	96.2	144.9
Agriculture...	0.4	0.7	0.9	1.1
Manufacturing.	12.6	25.2	36.6	55.6
All other.....	19.6	40.4	58.7	88.2
Delaware.......	1.5	3.5	5.1	7.7
Agriculture...	0.0	0.1	0.1	0.1
Manufacturing.	0.6	1.5	2.0	3.4
All other.....	0.8	2.0	3.0	4.2
Maryland.......	9.3	22.1	32.5	49.6
Agriculture...	0.2	0.3	0.3	0.3
Manufacturing.	2.3	5.3	7.8	12.0
All other.....	6.8	16.5	24.4	37.3
D.C............	3.9	6.9	9.9	14.7
Agriculture...	0.0	--	--	--
Manufacturing.	0.1	0.2	0.4	0.6
All other.....	3.7	6.7	9.5	14.1
Ohio...........	29.0	64.0	93.1	140.3
Agriculture...	0.6	0.9	1.2	1.5
Manufacturing.	11.9	27.0	37.7	56.8
All other.....	16.5	36.1	54.2	82.0
Indiana........	13.7	30.4	44.2	66.4
Agriculture...	0.7	1.0	1.2	1.6
Manufacturing.	5.7	13.1	18.3	27.4
All other.....	7.3	16.4	24.7	37.4
Illinois.......	34.6	73.9	107.5	161.7
Agriculture...	1.0	1.3	1.5	1.6
Manufacturing.	11.4	26.6	37.6	55.4
All other.....	22.1	46.0	68.4	104.7

continued--

Table 8. Gross Product Originating, by States continued--

(In billions 1958 dollars)

State	NPA estimate 1962	RRNA projections		
		1980	1990	2000
Michigan.......	22.5	54.0	78.4	117.8
Agriculture...	0.5	0.7	0.8	0.9
Manufacturing.	9.9	23.2	32.5	50.9
All other.....	12.1	30.1	45.1	66.0
Wisconsin......	11.2	25.2	36.8	55.5
Agriculture...	0.7	1.0	1.2	1.5
Manufacturing.	4.2	9.6	14.0	21.3
All other.....	6.3	14.6	21.6	32.7
Virginia.......	10.1	24.6	36.3	55.3
Agriculture...	0.4	0.6	0.8	0.8
Manufacturing.	2.3	6.4	9.4	14.9
All other.....	7.3	17.6	26.1	39.6
West Virginia..	4.1	8.0	11.6	17.6
Agriculture...	0.1	0.1	0.1	0.1
Manufacturing.	1.1	2.2	3.2	5.0
All other.....	2.9	5.7	8.3	12.5
Kentucky.......	6.4	14.4	21.0	32.0
Agriculture...	0.6	0.8	0.9	1.0
Manufacturing.	1.5	3.9	5.7	8.5
All other.....	4.3	9.7	14.4	22.5
Tennessee......	8.0	18.3	26.7	40.3
Agriculture...	0.5	0.7	0.8	0.9
Manufacturing.	2.5	6.6	9.6	14.7
All other.....	5.0	11.0	16.3	24.7
North Carolina.	10.8	25.6	37.5	56.8
Agriculture...	1.0	1.5	1.9	2.2
Manufacturing.	3.7	9.5	13.9	21.2
All other.....	6.0	14.6	21.7	33.4
South Carolina.	5.0	11.7	17.3	26.3
Agriculture...	0.4	0.6	0.8	0.9
Manufacturing.	1.8	4.4	6.4	9.9
All other.....	2.8	6.6	10.1	15.5

continued--

Table 8. Gross Product Originating, by States continued--

(In billions 1958 dollars)

State	NPA estimate 1962	RRNA projections		
		1980	1990	2000
Georgia........	9.3	22.9	33.5	50.9
Agriculture...	0.5	0.8	1.0	1.1
Manufacturing.	2.6	6.9	10.1	14.2
All other.....	6.2	15.2	22.4	35.6
Florida........	12.6	37.7	55.3	84.0
Agriculture...	0.6	1.1	1.4	1.6
Manufacturing.	1.8	5.7	8.3	12.8
All other.....	10.1	31.0	45.6	69.6
Alabama........	6.7	15.3	22.2	33.6
Agriculture...	0.4	0.5	0.6	0.6
Manufacturing.	2.0	5.0	7.1	10.1
All other.....	4.4	9.7	14.5	22.9
Mississippi....	3.7	8.8	13.0	19.9
Agriculture...	0.5	0.7	0.8	0.8
Manufacturing.	0.9	2.9	4.3	6.2
All other.....	2.3	5.1	7.9	12.9
Louisiana......	7.1	17.0	25.2	38.5
Agriculture...	0.4	0.6	0.7	0.9
Manufacturing.	1.2	2.9	4.3	6.7
All other.....	5.6	13.6	20.2	30.9
Arkansas.......	3.5	7.7	11.3	17.0
Agriculture...	0.5	0.7	0.8	0.9
Manufacturing.	0.8	2.5	3.6	5.3
All other.....	2.1	4.5	6.9	10.8
Minnesota......	9.3	21.4	31.1	47.0
Agriculture...	0.7	1.0	1.2	1.5
Manufacturing.	2.2	5.8	8.4	12.0
All other.....	6.4	14.7	21.5	33.5
Iowa...........	7.0	14.9	21.7	32.8
Agriculture...	1.1	1.5	1.7	1.9
Manufacturing.	1.6	3.9	5.6	8.4
All other.....	4.3	9.5	14.4	22.5

continued--

Table 8. Gross Product Originating, by States continued--

(In billions 1958 dollars)

State	NPA estimate 1962	RRNA projections		
		1980	1990	2000
Missouri........	12.5	25.8	37.3	55.8
Agriculture...	0.7	0.9	1.0	1.1
Manufacturing.	3.4	7.5	10.8	16.4
All other.....	8.3	17.4	25.5	38.3
North Dakota...	1.6	2.7	3.8	5.4
Agriculture...	0.6	0.6	0.7	0.7
Manufacturing.	0.0	0.2	0.3	0.5
All other.....	1.0	1.9	2.8	4.2
South Dakota...	1.7	3.2	4.6	6.7
Agriculture...	0.4	0.5	0.5	0.5
Manufacturing.	0.1	0.4	0.5	1.0
All other.....	1.1	2.4	3.6	5.2
Nebraska.......	4.0	8.2	11.8	17.6
Agriculture...	0.6	0.8	0.9	0.9
Manufacturing.	0.6	1.4	2.2	2.8
All other.....	2.8	6.0	8.7	13.9
Kansas.........	5.7	12.9	18.8	28.4
Agriculture...	0.6	0.8	0.9	0.9
Manufacturing.	1.1	3.2	4.7	6.7
All other.....	4.0	8.8	13.2	20.8
Oklahoma.......	5.8	12.6	18.3	27.4
Agriculture...	0.4	0.4	0.4	0.5
Manufacturing.	0.8	2.3	3.3	4.7
All other.....	4.6	10.0	14.6	22.2
Texas..........	25.5	61.1	89.8	136.7
Agriculture...	1.6	2.0	2.2	2.4
Manufacturing.	4.5	14.7	21.6	27.5
All other.....	19.4	44.3	66.0	106.8
Arizona........	3.7	9.4	14.5	23.2
Agriculture...	0.3	0.4	0.5	0.6
Manufacturing.	0.5	1.8	2.6	4.0
All other.....	3.0	7.2	11.4	18.6

continued--

Table 8. Gross Product Originating, by States
continued--

(In billions 1958 dollars)

State	NPA estimate 1962	PRNA projections 1980	1990	2000
New Mexico.....	2.3	5.2	7.5	11.4
Agriculture...	0.1	0.2	0.2	0.2
Manufacturing.	0.2	0.4	0.6	1.1
All other.....	2.0	4.6	6.7	10.1
Montana........	1.8	3.5	5.0	7.2
Agriculture...	0.3	0.3	0.3	0.3
Manufacturing.	0.2	0.5	0.6	1.0
All other.....	1.3	2.7	4.1	5.9
Idaho..........	1.6	3.5	5.1	7.5
Agriculture...	0.2	0.3	0.4	0.5
Manufacturing.	0.3	0.7	1.0	1.5
All other.....	1.1	2.5	3.7	5.5
Wyoming........	1.0	1.9	2.7	4.1
Agriculture...	0.1	0.1	0.1	0.1
Manufacturing.	0.1	0.2	0.2	0.5
All other.....	0.8	1.6	2.4	3.5
Utah...........	2.5	5.9	8.6	12.7
Agriculture...	0.1	0.1	0.1	0.1
Manufacturing.	0.5	1.3	1.9	2.7
All other.....	2.0	4.5	6.6	9.9
Colorado.......	5.3	11.7	17.1	25.8
Agriculture...	0.2	0.2	0.2	0.2
Manufacturing.	0.9	2.1	3.1	4.6
All other.....	4.2	9.3	13.8	21.0
Washington.....	8.6	19.2	28.1	42.4
Agriculture...	0.4	0.5	0.5	0.6
Manufacturing.	2.3	5.8	8.4	12.1
All other.....	5.9	12.9	19.2	29.7
Oregon.........	5.0	11.3	16.4	24.8
Agriculture...	0.3	0.3	0.3	0.3
Manufacturing.	1.3	3.2	4.6	6.6
All other.....	3.5	7.8	11.5	17.9

continued--

Table 8. Gross Product Originating, by States continued--

(In billions 1958 dollars)

State	NPA estimate 1962	RRNA projections		
		1980	1990	2000
California.....	54.8	129.1	189.1	286.7
Agriculture...	2.0	2.4	2.8	3.2
Manufacturing.	14.1	36.1	52.5	74.8
All other.....	38.8	90.6	133.8	208.7
Nevada.........	1.2	3.5	5.3	8.3
Agriculture...	0.0	0.0	0.0	0.0
Manufacturing.	0.1	0.2	0.3	0.5
All other.....	1.2	3.2	5.0	7.8
Alaska.........	0.8	2.0	3.1	4.9
Agriculture...	0.0	0.0	0.0	0.0
Manufacturing.	0.0	0.2	0.2	0.6
All other.....	0.7	1.8	2.9	4.3
Hawaii.........	1.9	4.8	7.2	11.1
Agriculture...	0.1	0.1	0.2	0.2
Manufacturing.	0.2	0.5	0.8	1.3
All other.....	1.6	4.1	6.2	9.6

Source: National Planning Association, Center for Economic Projections, State Projections to 1975: A Quantitative Analysis of Economic and Demographic Changes, Regional Economic Projections Series, October 1965; and RRNA estimates.

II. PROJECTIONS OF ECONOMIC AGGREGATES FOR CANADA, WESTERN EUROPE AND JAPAN

Economic aggregates for developed countries were prepared to serve as a basis for projecting U.S. exports of relevant commodities. In particular, population and GNP were projected for 23 country members of the Organisation for Economic Co-operation and Development (OECD).

Population

Projections of population are available from the United Nations for all countries for 1975, 1980 and 1985.1/ The projections for 1980 have been used for all countries except the United States (table 9).

The U.N. has also projected populations for the major population regions of the world to 1990 and 2000.2/ These projections have been used as a basis for projecting population by country for 1990 and 2000. It was assumed that each country would have the same share of the population of the region into which it fell in 1990 and 2000 as it had in 1985. For example, France was projected by the U.N. to have a 35 percent share of the

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1/ United Nations, Population Division, World Population Prospects, 1965-1985, As Assessed in 1968, Working Paper No. 30, 1969.
2/ United Nations, Population Division, World Population Prospects, 1965-2000, As Assessed in 1968, Working Paper No. 37, 1971. The U.N. made three projections (low, medium and high) for the regions. The medium projection was used.

Table 9. Population, OECD Countries, 1968 (Actual) and 1980, 1990, and 2000 (Estimated)

(In thousands)

Countries	1968	1980	1990	2000
European Community				
Belgium..........	9,619	10,150	10,779	11,455
France...........	49,915	55,320	59,459	63,191
Germany..........	60,184	61,054	64,334	68,372
Italy............	53,798	57,855	62,294	66,843
Luxembourg.......	336	391	422	448
Netherlands......	12,725	14,468	15,788	16,779
Total..........	186,577	199,238	213,076	227,088
Other OECD Europe				
Austria..........	7,350	7,778	8,282	8,802
Denmark..........	4,870	5,325	5,685	6,077
Finland..........	4,689	4,925	5,203	5,562
Greece...........	8,803	9,479	10,112	10,850
Iceland..........	201	252	288	307
Ireland..........	2,910	3,273	3,617	3,866
Norway...........	3,819	4,288	4,647	4,967
Portugal.........	9,497	10,283	11,128	11,940
Spain............	32,622	36,413	39,539	42,425
Sweden...........	7,912	8,553	9,061	9,686
Switzerland......	6,145	7,040	7,624	8,103
Turkey...........	33,540	46,527	61,093	78,899
United Kingdom...	55,391	59,548	63,994	68,407
Total..........	177,749	203,684	230,273	259,891
United States.....	201,152	232,412[a/]	266,319[a/]	300,789[a/]
Canada............	20,772	25,299	30,144	35,994
Japan.............	101,090	116,347	125,330	132,760
Grand total.......	687,340	776,980	865,142	956,522

a/ Bureau of the Census, Series C Projection.

Source: 1968--Organisation for Economic Co-operation and Development, Labor Force Statistics 1957-68, 1970, p. 4. 1980--United Nations, Population Division, World Population Prospects 1965-1985, As Assessed in 1968, Working Paper No. 30,

continued--

Table 9. Population, OECD Countries, 1968 (Actual) and 1980, 1990, and 2000 (Estimated) continued--

1967. 1990-2000--Japan estimated by United Nations, Population Division, World Population Prospects, 1965-2000, As Assessed in 1968, Working Paper No. 37, 1971; U.S. estimated by Department of Commerce, Current Population Report, Bureau of the Census Series P-25, No. 448, August 6, 1970; all others estimated by RRNA.

population of Western Europe in 1985; it was projected by RRNA to retain this share in 1990 and 2000. This method was followed for all countries except the United States and Japan. The U.N. made a separate projection for the latter, and the U.S. Bureau of the Census makes projections for the former.

Projections of Gross National Product

Projections of gross domestic product (GDP) growth rates between 1970 and 1980 have been made by OECD for each of its member countries.1/ These growth rates were applied to base year (1968) GNP's of the countries to determine their respective GNP's in 1980 (table 10). In projecting to 1990 and 2000, two major assumptions were made. First, it was assumed that in the future all OECD countries with the same per capita GNP, except Japan, would grow at the same rate. Second, it was assumed that the rate of growth of countries during any given decade would be approximately the same as the rate of growth of countries with similar per capita incomes during the previous decade.

For Japan, the OECD projection for 1980 was accepted, but after 1980 it was assumed that the Japanese rate of growth would decline by 50 percent, from 10 percent annual average growth to 5 percent annual average growth between 1990 and 2000. Deviations from these assumptions were made for a few individual countries, primarily in Southern Europe, which were judged to have extraordinarily good prospects for growth after a minimum (critical) level of income is attained.

Given the above assumptions, most OECD countries will have a level of per capita income at least equal to or greater than that of the United States today. While the Japanese rate of growth since World War II has been vigorous, it is judged that such a high rate

1/ Organisation for Economic Co-operation and Development, The Growth of Output 1960-1980, December 1970, p. 80.

Table 10. Gross National Product for Selected Countries, 1968 (Actual) and 1980, 1990 and 2000 (Estimated)

Countries	Gross national product				Annual growth rate			Per capita GNP a/			
	1968 b/	1980	1990	2000	1968-1980 c/	1980-1990 d/	1990-2000 d/	1968	1980	1990	2000
	mil. of U.S. dol. e/							dol.			
Western Europe											
West Germany	132,480	227,269	346,244	522,482	4.6	4.3	4.2	2,200	3,720	5,380	7,640
France	126,230	254,000	386,969	583,936	6.0	4.3	4.2	2,530	4,590	6,510	9,240
Netherlands	25,230	43,282	77,509	116,961	4.6	6.0	4.2	1,980	2,990	4,910	6,970
Belgium	20,750	36,005	54,854	82,775	4.7	4.3	4.2	2,160	3,550	5,090	7,230
Luxembourg	710 f/	1,043	1,868	2,819	3.0	6.0	4.2	2,120 f/	2,670	4,430	6,290
Austria	11,400	20,240	36,246	54,695	4.9	6.0	4.2	1,550	2,602	4,380	6,210
Switzerland	17,160	25,335	38,598	58,244	3.3	4.3	4.2	2,790	3,600	5,060	7,190
Total	333,960	607,174	942,288	1,421,912	5.1	4.5	4.2	2,280	3,890	5,650	8,030
Northern Europe											
United Kingdom	102,670	149,826	268,308	404,877	3.2	6.0	4.2	1,850	2,520	4,190	5,920
Sweden	25,570	39,069	59,552	89,864	3.6	4.3	4.2	3,230	4,570	6,570	9,280
Denmark	12,390	19,384	29,532	44,564	3.8	4.3	4.2	2,540	3,640	5,190	7,330
Norway	9,020	15,122	23,038	34,764	4.4	4.3	4.2	2,360	3,530	4,960	7,000
Finland	8,010	13,584	24,326	36,708	4.5	6.0	4.2	1,710	2,760	4,680	6,600
Ireland	2,980	5,230	9,366	16,773	4.8	6.0	6.0	1,020	1,600	2,590	4,340
Iceland	450	763	1,162	1,753	4.5	4.3	4.2	2,240	3,030	4,030	5,710
Total	161,090	242,998	415,284	629,303	3.5	5.5	4.2	2,020	2,820	4,490	6,360
Southern Europe											
Italy	74,980	144,179	258,196	389,618	5.6	6.0	4.2	1,390	2,490	4,140	5,830
Spain	25,200	47,910	85,797	153,645	5.5	6.0	6.0	770	1,320	2,170	3,620
Portugal	5,010	11,411	20,435	36,595	7.1	6.0	6.0	530	1,110	1,840	3,060
Greece	7,550	18,184	32,564	58,316	7.6	6.0	6.0	860	1,920	3,220	5,370
Yugoslavia	9,490 f/	22,320	39,971	71,580	6.8	6.0	6.0	480 f/	980	1,610	2,690
Turkey	11,600	25,546	45,748	81,926	6.8	6.0	6.0	350	549	750	1,040
Total	133,830	269,550	482,711	791,680	6.0	6.0	5.1	850	1,470	2,310	3,330
Japan	141,800	445,025	917,194	1,494,017	10.0	7.5	5.0	1,400	3,820	7,320	11,250
Canada	62,440	117,368	178,810	269,824	5.4	4.3	4.2	3,010	4,640	5,932	7,509
United States g/	880,770	1,435,300	2,092,900	3,159,300	4.3	3.8	4.2	4,380	6,176	7,853	10,503
Total EEC	380,380	705,778	1,125,640	1,698,591	5.3	4.8	4.2	2,040	3,540	5,280	7,480
Total	1,713,890	3,117,415	5,072,757	7,992,555	5.1	5.0	4.7	2,420	3,900	5,700	8,130

a/ Total GNP divided by estimated population (see table 9).
b/ Actual: OECD, National Accounts of OECD countries.
c/ Estimated: OECD, The Growth of Output, December 1970, p. 80.
d/ Estimated by RRNA.
e/ 1968 market prices and exchange rate.
f/ 1967 data.
g/ Estimated by RRNA (see tables 1 and 2).

of growth cannot be maintained as the economic base of the country increases to Western European and U.S. standards.

ANNEX A-2. CRUDE PETROLEUM AND PETROLEUM PRODUCTS

CONTENTS

I. U.S. SUPPLY AND DEMAND BY REGION, 1970

Crude petroleum and petroleum products produced, consumed, and transported within, and to and from, the United States exceed all other bulk commodities in magnitude whether measured on a cubic or a weight basis. Imports in 1970 are estimated at approximately 200 million short tons, and tidewater coastal movements between U.S. coastal areas, at approximately 100 million tons. The inland movement of products approximated 200 million tons, and barge movements of crude petroleum and products on the Mississippi were approximately 20 million tons. The weight of total consumption of petroleum products in the United States in 1970 is estimated at approximately 800 million tons.1/

Meaningful analysis and projection of the supply and demand of petroleum and petroleum products in terms

1/ All petroleum data available from the U.S. Government and industry are expressed in terms of 42-gallon barrels. For purposes of this study it is necessary to convert these data to a weight basis in common with all other quantitative data to be employed in the study. The specific gravity of crude petroleum from different sources and of different petroleum products varies somewhat. Thus the conversion factor from barrels to short tons for motor gasoline is 7.72 and ranges down to 6.04 for residual fuel oils. The conversion factor for average crudes from the U.S. is 6.729, and for crudes from principal foreign exporting countries is approximately 6.70 for Middle East countries and 6.2 for Venezuela. An average conversion of 6.5 is employed in this report as a matter of convenience for crude petroleum and products.

of their implications for possible future deepwater port needs require regional differentiation. For this purpose we use the five regions of the country for which data are regularly reported by the Bureau of Mines, known as Petroleum Administration for Defense (PAD) Districts I through V (figure 1).

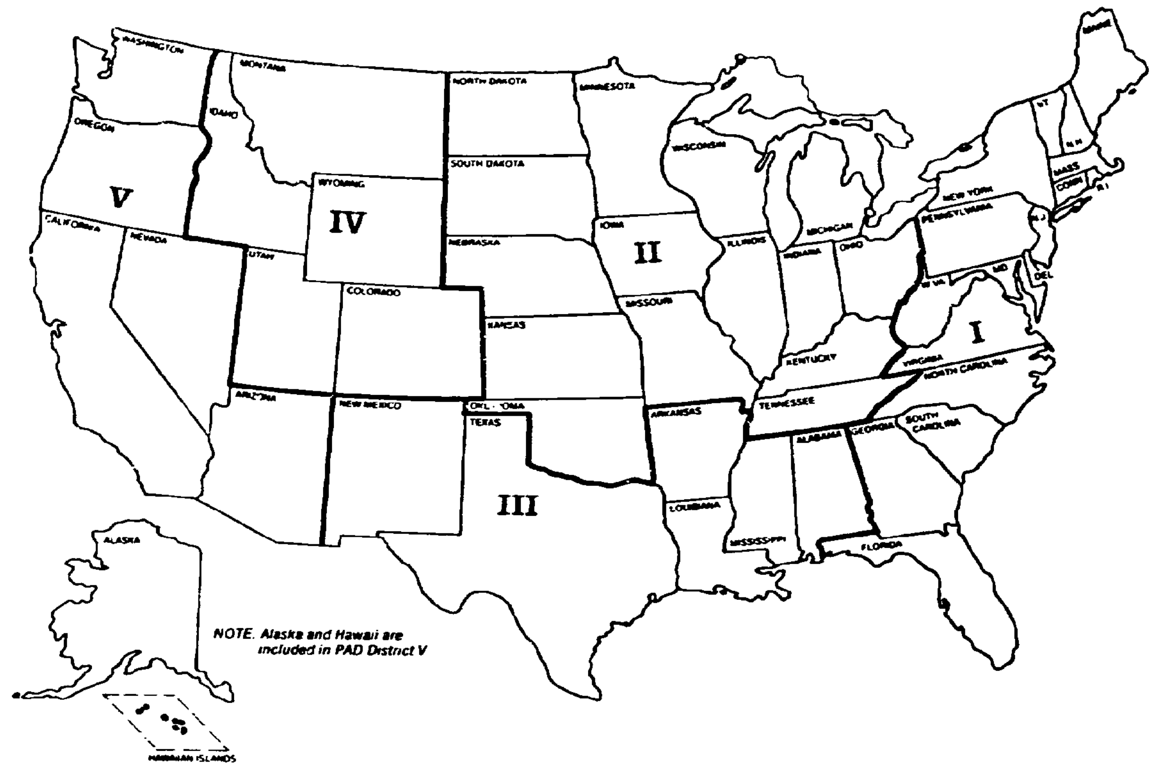
District I

The supply and demand for crude petroleum and products by PAD districts in 1970 are shown in table 1. In that year total U.S. demand for petroleum products was 14.7 million barrels per day, of which 5.85 million barrels, or approximately 40 percent, were consumed in the Atlantic tier of states ranging from Maine through Florida and classified as District I. When compared with the others, District I is notable for the fact that it has the largest volume of demand, but produces virtually no petroleum of its own (less than 1 percent of product demand).

Thus District I is virtually dependent upon external sources of supply for the crude petroleum requirements of its refineries and for petroleum products not supplied from its refineries. Of the total supply of 6.0 million barrels per day, 58 percent was in the form of crude petroleum and products from other districts in the United States, and approximately 40 percent was imported from foreign sources, of which 29 percent was imported as refined products and 11 percent as crude petroleum and unfinished oils.

As shown in tables 2 and 3, District I's only significant domestic source of crude oil and refined products was District III, which is composed of the tier of Gulf States ranging from Alabama through New Mexico and including Arkansas. Combined receipts of 1.25 billion barrels, or 192 million short tons, from District III accounted for 55 percent of the total petroleum supply in District I. Of this, 80 percent was in the form of petroleum products and 20 percent in the form of crude oil. Foreign imports of crude oil and natural gas liquids accounted for approximately 44 percent of the

Figure 1. Petroleum Administration for
Defense (PAD) Districts



total supply of crude. Refinery output of 543 million barrels accounted for only 25 percent of the total supply of refined products.

Tables 4 and 5 show domestic receipts of crude and products from U.S. origins by mode of transportation, in barrels and short tons. Virtually all of the crude oil shipped to District I from District III was by tidewater, and shipments of products were divided approximately equally between pipeline on the one hand and tidewater and barge on the other.

District II

District II, composed of the Central States ranging from Tennessee, Kentucky, Ohio and Michigan on the east to the Dakotas, Nebraska, Kansas and Oklahoma on the west, accounted for approximately 28 percent of total U.S. demand for petroleum products in 1970, and ranked next to District I (table 1). Of its total available supply, approximately one-third came from indigenous production, with most of the balance coming from other districts, mainly in the form of crude and refined products from District III. Foreign imports were approximately 7 percent of total supply. Approximately 55 percent of natural gas liquids and petroleum products is transported from District III to District II via pipeline, with the balance moving by barge (tables 4 and 5). Data on the transport of crude oil is not reported by the Bureau of Mines, but virtually all of this movement is understood to be via pipeline.

District III

District III is a large producer of crude oil and refined products. Of its total supply in 1970 of 8.1 million barrels per day, virtually all was from indigenous production, and 5.5 million barrels, or slightly over two-thirds, were shipped to other districts (table 1). District III accounted for 88 percent of total shipments to other districts for the United States as a whole. Of these shipments, 60 percent were refined

products, and the balance was crude petroleum (tables 2 and 3).

District IV

District IV, composed of most of the Rocky Mountain States, accounts for less than 3 percent of U.S. demand for petroleum products, and is a surplus producer of crude oil and refined products. Most of its crude is shipped to District II, where it accounts for less than 7 percent of total petroleum product demand, and most of its products are shipped to District V, where they account for approximately 5 percent of total demand (tables 1, 2 and 3).

District V

District V, composed of the Pacific Coast States and Nevada, Alaska and Hawaii, accounts for 13 percent of total U.S. demand for petroleum products. It is almost self-sufficient in refined products, with receipts from Districts III and IV and from foreign imports accounting for less than 10 percent of total requirements, and with overall domestic and foreign shipments and receipts being approximately in balance. However, District V has a crude petroleum deficit of approximately 25 percent of total requirements, almost all of which is supplied through foreign imports (tables 1, 2, and 3).

Summary

In summary, Districts III and IV are substantial surplus producers of crude petroleum and refined products, with most of this surplus being shipped to Districts I and II. Indigenous production and receipts from Districts III and IV accounted for 90 percent of total requirements in District II. District V is self-sufficient in refining capacity and is marginally dependent on external (primarily foreign) sources of supply of crude.

District I, however, is virtually totally dependent upon external sources of supply of crude petroleum, and in 1970 had a refinery output equal to only one-quarter of its total demand. It accounted for 71 percent of U.S. foreign imports of crude oil and refined products of 3.4 million barrels per day. Its total foreign imports and receipts from other districts of 6.0 million barrels per day is the equivalent of 2.14 billion barrels per annum, or 330 million short tons. Its waterborne imports from overseas and domestic sources of 1.6 million barrels were the equivalent of approximately 245 million short tons.

Thus it is clear that the supply of crude petroleum and products to District I presently involves a substantial volume of oceanborne transport from U.S. and foreign sources, and that the magnitude of this movement far surpasses that related to the supply of any other region of the country. By contrast, the supply of petroleum and products to Districts II, III, and IV is almost wholly from indigenous sources or balanced out through interdistrict transfers. Total imports in 1970 into District V of 484 million barrels daily equal approximately 26 million short tons.

Table 1. Supply, Demand and Stocks of All Oils by PAD Districts, 1970
(In thousands of barrels daily)

Supply, demand and stocks	PAD district						Total
	I	II	III	IV	Subtotal	V	
Domestic products:							
Crude and lease condensate..........	32	1,170	6,504	673	8,379	1,252	9,631
Natural gas plant liquids.............	24	263	1,307	34	1,628	52	1,680
Receipts from other districts............	3,513	2,405	86	46	21	193	--
Imports:							
Crude oil............	579	317	--	48	944	380	1,324
Unfinished oils.......	83	--	3	--	86	22	108
Refined products......	1,785	53	57	9	1,904	82	1,986
Other hydrocarbons and hydrogen inputs.......	--	1	2	--	3	14	17
Total new supply......	6,016	4,209	7,959	810	12,968	1,995	14,746
Unaccounted for crude oil..........	2	-18	5	-5	-16	--	-16
Processing gain......	44	94	166	5	309	50	359
Total supply..........	6,062	4,285	8,130	810	13,261	2,045	15,089
Change in stocks of all oil............	+66	+60	+32	-5	+153	-50	+103
Total disposition of primary supply.......	5,996	4,225	8,098	815	13,108	2,095	14,986
Exports:							
Crude oil............	--	1	12	--	13	1	14
Refined products......	21	11	97	--	129	115	244
Shipments to other districts...........	120	149	5,506	444	193	24	--
Crude losses (est. for individual Districts I-IV).........	2	3	5	1	11	1	12

continued--

Table 1. Supply, Demand and Stocks of All Oils by PAD Districts, 1970 continued--
(In thousands of barrels daily)

Supply, demand and stocks	PAD district						Total
	I	II	III	IV	Subtotal	V	
Domestic demand for products:							
Gasoline, total........	2,000	2,033	755	177	4,965	874	5,839
Motor gasoline........	1,988	2,020	741	175	4,924	860	5,784
Aviation gasoline.....	12	13	14	2	41	14	55
Jet fuel, total........	349	193	94	23	659	306	965
Naphtha-type..........	66	43	43	3	155	94	249
Kerosine-type.........	283	150	51	20	504	212	716
Ethane (inc. ethylene).	5	27	196	--	228	2	230
Liquefied gases........	125	305	507	13	950	66	1,016
Kerosine...............	125	84	43	6	258	5	263
Distillate fuel oil....	1,297	750	190	71	2,308	232	2,540
Residual fuel oil......	1,635	199	87	25	1,946	258	2,204
Petrochemical feed-stocks................	24	34	205	1	264	13	277
Special napthas........	13	19	35	--	72	13	85
Lubricants.............	53	38	31	1	123	13	136
Wax....................	6	3	2	--	11	2	13
Coke...................	32	77	77	9	195	17	212
Asphalt................	118	148	79	25	370	50	420
Road oil...............	2	15	--	5	22	4	26
Still gas for fuel....	56	127	161	14	358	91	449
Miscellaneous products.	8	9	16	--	33	8	41
Total.................	5,853	4,061	2,478	370	12,762	1,954	14,716

Source: U.S. Department of the Interior, Bureau of Mines, Mineral Industry Surveys, "Monthly Petroleum Statement," December 1970, prepared by the Division of Fossil Fuels, March 23, 1970.

Table 2. Supply and Demand of Crude Oil, Natural Gas Liquids and Total Products by PAD Districts for 1970

(In millions of barrels)[a/]

Supply and demand	Total	PAD district I	II	III	IV	V
Crude oil and natural gas liquids						
Production:						
Crude oil	3,515.3	11.7	427.1	2,374.0	245.6	457.0
Natural gas liquids	613.2	8.8	96.0	477.1	12.4	19.0
Total domestic rect. from dist.	--	278.1	631.5	5.5	--	14.2
I	--	--	--	--	--	--
II	--	8.4	--	1.5	--	--
III	--	265.0	531.4	--	--	2.9
IV	--	3.7	100.0	4.0	--	11.3
V	--	1.1	--	--	--	--
Foreign imports - crude oil	483.3	211.3	115.7	--	17.5	138.7
Domestic shipments	--	--	9.9	799.4	119.0	1.1
Foreign exports - crude oil	5.1	--	0.4	4.4	--	0.4
Runs to stills	4,165.4	474.5	1,175.3	1,746.2	145.3	624.2
Total products, including natural gas liquids						
Refinery output	4,136.5	543.5	1,184.4	1,625.7	144.5	638.4
Total domestic rect. from dist.	--	1,004.1	246.4	25.9	16.8	56.2
I	--	--	43.8	--	--	--
II	--	19.7	--	24.8	--	--
III	--	983.7	194.9	--	9.9	21.9
IV	--	--	7.7	1.1	--	34.3
V	--	0.7	--	--	6.9	--
Foreign imports	722.7	651.5	17.2	20.8	3.3	29.9
Domestic shipments	--	43.8	44.5	1,210.3	43.1	7.7
Foreign exports	89.1	7.7	4.0	35.4	--	42.0
Consumptio.. (demand)	5,371.3	2,136.3	1,482.3	904.5	135.1	713.2

Note: Figures may not add up to the totals due to rounding.

a/ Converted from thousands of barrels daily.

Source: U.S. Department of the Interior, Bureau of Mines, Mineral Industry Surveys, "Monthly Petroleum Statement," December 1970, prepared by the Division of Fossil Fuels, March 23, 1970, table 25.

Table 3. Supply and Demand of Crude Oil, Natural Gas Liquids and Total Products by PAD Districts for 1970

(In millions of short tons)[a/]

Supply and demand	Total	PAD district I	II	III	IV	V
Crude oil and natural gas liquids						
Production:						
Crude oil	540.8	1.8	65.7	365.2	37.8	70.3
Natural gas liquids	94.3	1.4	14.8	73.4	1.9	2.9
Total domestic receipts from district	--	42.8	97.2	0.8	--	2.2
I	--	--	--	--	--	--
II	--	1.3	--	0.2	--	--
III	--	40.8	81.8	--	--	0.4
IV	--	0.6	15.4	0.6	--	1.7
V	--	0.2	--	--	--	--
Foreign imports - crude oil	74.4	32.5	17.8	--	2.7	21.3
Domestic shipments	--	--	1.5	123.0	18.3	0.2
Foreign exports - crude oil	0.8	--	0.1	0.7	--	0.1
Runs to stills	640.8	73.0	180.8	268.6	22.4	96.0
Total products, including natural gas liquids						
Refinery output	636.4	83.6	182.2	250.1	22.2	98.2
Total domestic receipts from district	--	154.5	37.9	4.0	2.6	8.6
I	--	--	6.7	--	--	--
II	--	3.0	--	3.8	--	--
III	--	151.3	30.0	--	1.5	3.4
IV	--	--	1.2	0.2	--	5.3
V	--	0.1	--	--	1.1	--
Foreign imports	111.2	100.2	2.6	3.2	0.5	4.6
Domestic shipments	--	6.7	6.8	186.2	6.6	1.2
Foreign exports	13.7	1.2	0.6	5.4	--	6.5
Consumption (demand)	826.4	328.7	228.0	139.2	20.8	109.7

Note: Figures may not add up to the totals due to rounding.
a/ Converted from barrels. Conversion factor: 6.5 barrels equal 1 short ton.
Source: See table 2.

Table 4. Domestic Receipts by District of Origin and Mode of Transportation, 1970
(In millions of barrels)

District of origin	Crude oil and natural gas liquids				Total products			
	Pipeline[a]	Tidewater	Barge	Total	Pipeline	Tidewater	Barge	Total
District I receipts								
II........	10.4	--	--	10.4	9.9	--	--	9.9
III........	13.0	235.9	--	248.9	513.5	461.6	23.2	998.3
IV........	--	--	--	--	--	--	--	--
V........	--	0.3	--	0.3	--	1.7	--	1.7
District II receipts								
I........	0.0	--	--	0.0	43.8	--	--	43.8
III........	51.4	--	17.7	69.1	66.0	--	77.9	143.9
IV........	--	--	--	--	7.7	--	--	7.7
V........	--	--	--	--	--	--	--	--
District III receipts								
I........	--	--	--	--	--	--	--	--
II........	2.7	--	--	2.7	23.5	--	--	23.5
IV........	--	--	--	--	--	--	--	--
V........	--	--	--	--	--	--	--	--
District IV receipts								
I........	--	--	--	--	--	--	--	--
II........	--	--	--	--	--	--	--	--
III........	1.1	--	--	1.1	8.7	--	--	8.7
V........	--	--	--	--	--	--	--	--
District V receipts								
I........	--	--	--	--	--	--	--	--
II........	--	--	--	--	--	--	--	--
III........	--	--	--	--	18.4	3.1	--	21.5
IV........	--	--	--	--	18.2	--	--	18.2

a/ Figures presented are for natural gas liquids; no data presented for crude oil.
Source: U.S. Department of the Interior, Bureau of Mines, Mineral Industry Surveys, "Monthly Petroleum Statement" December 1970, prepared by the Division of Fossil Fuels, March 23, 1970, tables 12, 13 and 14.

Table 5. Domestic Receipts by District of Origin and Mode of Transportation, 1970
(In millions of short tons[a/])

District of origin	Crude oil and natural gas liquids				Total products			
	Pipeline[b/]	Tidewater	Barge	Total	Pipeline	Tidewater	Barge	Total
				District I receipts				
II..........	1.6	--	--	1.6	1.5	--	--	1.5
III..........	2.0	36.3	--	38.3	79.0	71.0	3.6	153.6
IV..........	--	--	--	--	--	--	--	--
V..........	--	0.0	--	0.0	--	0.3	--	0.3
				District [illegible] receipts				
I..........	0.0	--	--	0.0	6.7	--	--	6.7
III..........	7.9	--	2.7	10.6	10.2	--	12.0	22.1
IV..........	--	--	--	--	1.2	--	--	1.2
V..........	--	--	--	--	--	--	--	--
				District III receipts				
I..........	--	--	--	--	--	--	--	--
II..........	0.4	--	--	0.4	3.6	--	--	3.6
IV..........	--	--	--	--	--	--	--	--
V..........	--	--	--	--	--	--	--	--
				District IV receipts				
I..........	--	--	--	--	--	--	--	--
II..........	--	--	--	--	--	--	--	--
III..........	0.2	--	--	0.2	1.3	--	--	1.3
V..........	--	--	--	--	--	--	--	--
				District V receipts				
I..........	--	--	--	--	--	--	--	--
II..........	--	--	--	--	--	--	--	--
III..........	--	--	--	--	2.8	0.5	--	3.3
IV..........	--	--	--	--	2.8	--	--	2.8

a/ Converted from thousands of barrels; conversion factor: 6.5 barrels equal 1 short ton.

b/ Figures presented are for natural gas liquids; no data presented for crude oil.

Source: See table 4.

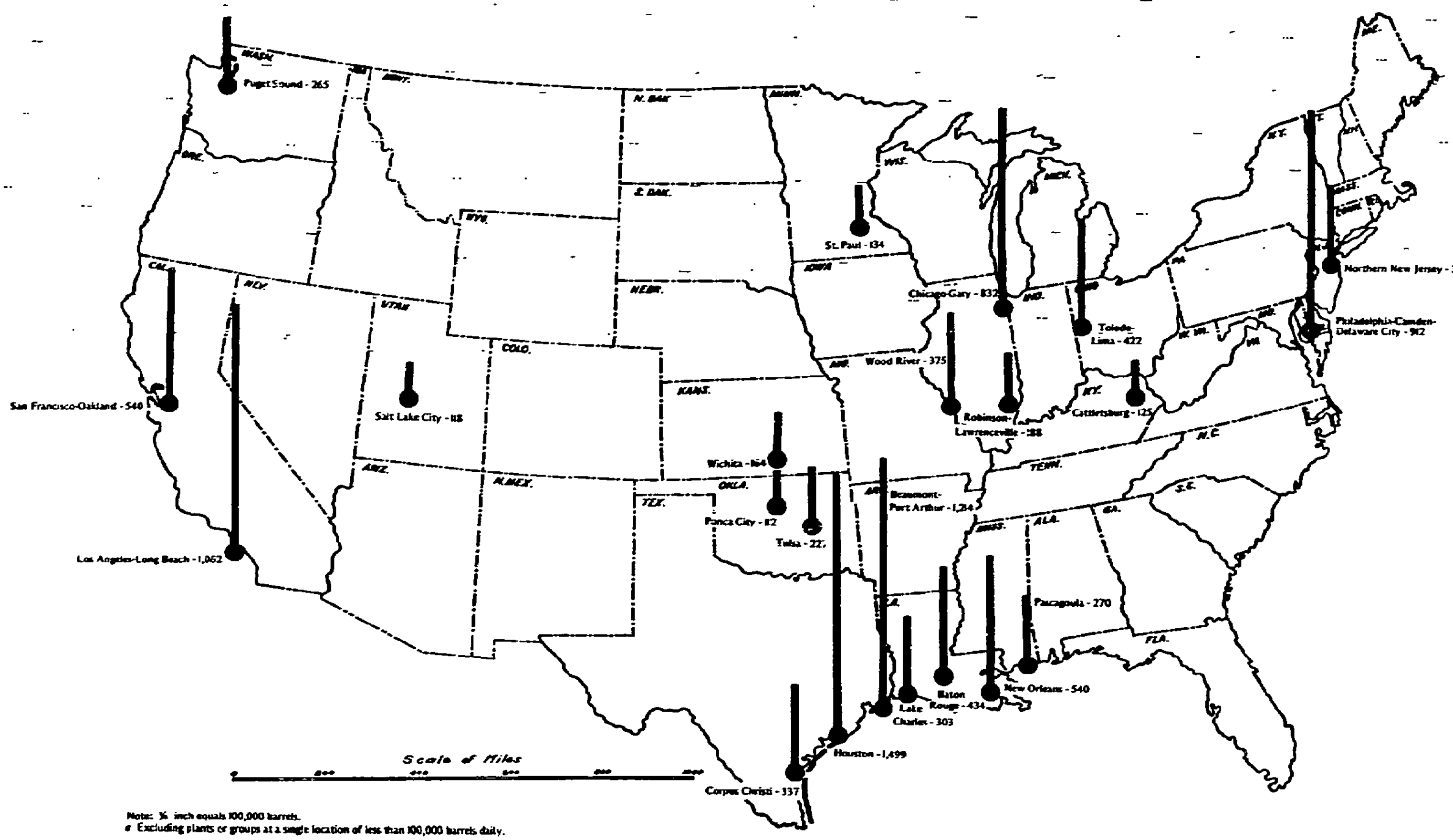
II. LOCATIONAL CHARACTERISTICS OF U.S. PETROLEUM REFINERIES

Figure 2 shows the geographic location of refinery capacity in the United States as of the end of 1970. For the nation as a whole, the particularly noteworthy locational characteristics are the heavy concentrations of refinery capacity, and the tendency for such concentrations to occur in the coastal areas and along inland waterways. On the west coast, the Los Angeles-Long Beach area alone has a capacity of over 1 million barrels per day, and another 540,000 barrel-per-day capacity exists in the San Francisco-Oakland area. On the Texas gulf coast, the Houston-Beaumont-Port Arthur area has a capacity of over 2.7 million barrels per day, while Corpus Christi has a capacity of 337,000 barrels per day. New Orleans, Baton Rouge, and Lake Charles in Louisiana and Pascagoula in Mississippi have a capacity of 1.5 million barrels. This combined capacity of 6.2 million barrels daily is well over half of total U.S. refinery capacity.

Total refinery capacity in the East Coast States comprising District I is approximately 1.5 million barrels per day. This corresponds almost exactly with the refinery output in these states shown in table 2. In the absence of refinery expansion, all increments in petroleum product consumption in these states would have to be supplied from either foreign or other U.S. domestic sources.

Eighty-five percent of District I refinery capacity is concentrated along coastal areas and waterways in New York, New Jersey, Pennsylvania, and Delaware. Three-quarters of this capacity is served by the

FIGURE 2. LOCATION OF PETROLEUM REFINING CAPACITY IN ONE THOUSAND BARRELS DAILY*



Note: ¾ inch equals 100,000 barrels.
* Excluding plants or groups at a single location of less than 100,000 barrels daily.

Source: Oil and Gas Journal, March 22, 1971.

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Delaware Bay and River, with most of the balance being served through the Port of New York. Most of the remaining capacity in District I is located in western New York and Pennsylvania and in Virginia on the Lower Chesapeake Bay. In the states of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, North Carolina, South Carolina, Georgia and Florida, there is a total capacity of only 17,500 barrels per day.

Thus for the east coast, as well as for the United States as a whole, refinery capacity tends to be located along the coasts and navigable waterways and, except for refineries in the gulf coast area supplying products to Districts I and II, close to the point of consumption.

III. ANALYSIS OF FOREIGN IMPORTS AND OTHER WATERBORNE PETROLEUM MOVEMENTS

Details on the product composition, origins, and destination districts of petroleum imports are shown in tables 6, 7, and 8. In 1970 about half of foreign crude imports came from Canada and went principally to Districts II and V. So far as is known, none of the imports from Canada are waterborne. Most of the remainder came from the Latin America-Caribbean and Middle East-Africa areas, and almost all of that went to District I.

Imports of refined products consist essentially of the movement of residual fuel oil into District I from the Latin America-Caribbean area, including Puerto Rico and the Virgin Islands. District I accounted for 90 percent of imports of refined products, and residual fuel oil accounted for 72 percent of total refined product imports, of which nearly 80 percent went to District I. The Latin America-Caribbean and Puerto Rico-Virgin Islands areas accounted for 86 percent of total U.S. imports of refined products.

As shown in tables 9 and 10, waterborne movements of petroleum within the United States are dominated by the tidewater movement of crude oil and products from the gulf coast to the east coast (697.5 million barrels in 1970 of a total tidewater and barge movement of 821 million barrels for the United States). There is a negligible movement by water from the gulf coast to the west coast and by barge from the gulf coast to District I. Nearly 100 million barrels moved from the gulf coast to District II by barge in 1970, of which about half was gasoline.

Table 6. Imports of Foreign Crude Oil and Refined Products into the United States, 1970[a]

(In thousands of barrels)

Imports and destinations	Canada[b]		Latin America-Caribbean		Europe		Middle East-Africa		Far East		Puerto Rico-Virgin Is.		Total	
	Annual	Per day	Annual	Per day	Annual	Per day	Annual	Per day	Annual	Per day	Annual	Per day	Annual	Per day
Foreign crude oil														
District:														
I..............	31,751	87	97,643	268	--	--	82,009	225	--	--	--	--	211,403	579
II..............	115,613	317	--	--	--	--	--	--	--	--	--	--	115,613	317
III.............	--	--	--	--	--	--	--	--	--	--	--	--	--	--
IV..............	17,573	48	--	--	--	--	--	--	--	--	--	--	17,573	48
V...............	80,321	220	8,465	23	--	--	24,248	66	25,670	70	--	--	138,704	380
Total..........	245,258	672	106,108	291	--	--	106,257	291	25,670	70	--	--	483,293	1,324
Refined products														
District:														
I..............	8,587	24	509,232	1,395	64,219	176	2,671	7	133	0	96,873	265	681,716	1,868
II..............	17,364	48	1,959	5	--	--	--	--	--	--	--	--	19,323	53
III.............	--	--	17,471	48	347	1	121	0	--	--	3,822	10	21,761	60
IV..............	3,192	9	--	--	--	--	--	--	--	--	--	--	3,192	9
V...............	5,329	15	27,567	76	--	--	4,413	12	798	2	--	--	38,107	104
Total..........	34,472	94	556,229	1,524	64,566	177	7,205	20	931	3	100,695	276	764,099	2,093

Note: Individual categories may not add up to the totals due to rounding.

a/ Reported to the Bureau of Mines.

b/ Includes some Athabasca hydrocarbons.

Source: Foreign crude oil -- U.S. Department of the Interior, Bureau of Mines, Mineral Industry Surveys, "Monthly Petroleum Statement" December 1970, prepared by the Division of Fossil Fuels, March 23, 1970, table 15. Refined products -- American Petroleum Institute, Division of Statistics and Economics, Weekly Statistical Bulletin, March 26, 1971.

Table 7. Imports of Foreign Crude Oil[a] by PAD Districts and Country of Origin, 1969 and 1970

(In thousands of barrels)

PAD district and country of origin	1969	1970
All districts		
Abu Dhabi	5,051	23,047
Algeria	358	2,093
Angola	424	--
Bolivia	5,596	534
Canada[b]	203,298	245,258
Chile	1,464	--
Colombia	15,55[illegible]	7,313
Egypt	14,778	7,626
Indonesia	32,271	25,670
Iran	15,306	12,184
Kuwait	12,539	12,123
Libya	48,862	17,156
Neutral Zone	15,864	8,398
Nigeria	17,958	17,490
Peru	216	--
Qatar	191	--
Saudi Arabia	12,665	6,140
Trinidad	--	265
Venezuela	111,722	97,996
Total[b]	514,114	483,293
To District I		
Abu Dhabi	--	16,047
Algeria	358	2,093
Angola	424	--
Bolivia	--	--
Canada	26,355	31,751
Colombia	14,297	7,180
Egypt	14,778	7,051
Iran	5,874	1,324
Kuwait	12,055	10,189
Libya	48,614	17,156
Neutral Zone	15,864	8,398
Nigeria	17,958	17,490
Qatar	191	--
Saudi Arabia	8,115	1,686
Trinidad	--	265
Venezuela	104,124	90,773
Total	269,007	211,403

continued--

Table 7. Imports of Foreign Crude Oil[a] by PAD Districts and Country of Origin, 1969 and 1970 continued--

(In thousands of barrels)

PAD district and country of origin	1969	1970
To District II		
Canada[b]............................	88,434	115,613
To District III		
Venezuela............................	--	--
To District IV		
Canada...............................	12,714	17,573
To District V		
Abu Dhabi............................	5,051	7,000
Bolivia..............................	5,596	534
Canada...............................	75,795	80,321
Chile................................	1,464	--
Colombia.............................	1,254	708
Indonesia............................	32,271	25,670
Iran.................................	9,432	10,860
Kuwait...............................	484	1,934
Libya................................	248	--
Peru.................................	216	--
Saudi Arabia.........................	4,550	4,454
Venezuela............................	7,598	7,223
Total................................	143,959	138,704

a/ Reported to the Bureau of Mines.
b/ Includes some Athabasca hydrocarbons.

Source: See table 1.

Table 8. Imports of Petroleum Products and Receipts from Puerto Rico and the Virgin Islands, Total All Districts and District I, 1969 and 1970

(In thousands of barrels)

PAD district	1969	1970
All districts		
Gasoline, total	22,709	24,320
Receipts from Puerto Rico	20,709	21,080
Receipts from Virgin Islands	825	1,235
Motor gasoline	1,175	2,005
Naphtha-type jet fuel, total	5,134	7,060
Bonded aircraft fuel	3,754	2,952
Receipts from Virgin Islands	273	--
Other	1,107	4,108
Kerosine-type jet fuel, total	40,405	44,992
Bonded aircraft fuel	38,527	43,918
Receipts from Puerto Rico	112	--
Other	1,766	1,074
Liquefied petroleum gases	12,651	19,161
Kerosine, total	965	1,451
Receipts from Puerto Rico	--	--
Receipts from Virgin Islands	929	953
Other	36	498
Distillate fuel oil, total	50,883	53,903
Bonded ships bunker	5,279	4,996
Receipts from Puerto Rico	5,407	5,492
Receipts from Virgin Islands	6,321	4,021
No. 4 fuel oil	27,392	25,607 a/
Other	6,484	13,787
Residual fuel oil, total	461,611	557,845
Bonded ships bunker	42,260	39,707
Receipts from Puerto Rico	--	--
Receipts from Virgin Islands	24,641	52,453
Other	394,710	465,685
Petrochemical feedstocks, total	40	5,195
Receipts from Puerto Rico	40	3,650
Other	--	1,545
Special napthas	3,191	2,111
Lubricants	163	224
Wax	158	117
Asphalt	4,761	6,201
Plant condensate	--	2,258
Unfinished oils, local	38,766	39,261
Receipts from Virgin Islands	9,564	9,833
Other	29,202	29,428
Total	641,437	764,099

continued--

Table 8. Imports of Petroleum Products and Receipts from Puerto Rico and the Virgin Islands, Total All Districts and District I, 1969 and 1970 continued--

(In thousands of barrels)

PAD district	1969	1970
District I		
Gasoline, total	22,112	24,006
Receipts from Puerto Rico	20,709	21,080
Receipts from Virgin Islands	825	1,235
Motor gasoline	578	1,691
Naphtha-type jet fuel, total	1,976	4,493
Bonded aircraft fuel	1,609	1,346
Receipts from Virgin Islands	273	--
Other	94	3,147
Kerosine-type jet fuel, total	23,031	25,382
Bonded aircraft fuel	22,102	25,239
Receipts from Puerto Rico	112	--
Other	817	143
Liquefied petroleum gases	559	2,124
Kerosine, total	960	1,349
Receipts from Puerto Rico	--	--
Receipts from Virgin Islands	929	953
Other	31	396
Distillate fuel oil, total	47,720	49,410
Bonded ships bunker	3,587	3,248
Receipts from Puerto Rico	5,407	5,492
Receipts from Virgin Islands	6,321	4,021
No. 4 fuel oil	27,392	25,607 a/
Other	5,013	11,042
Residual fuel oil, total	440,983	536,968
Bonded ships bunker	29,294	27,052
Receipts from Puerto Rico	--	--
Receipts from Virgin Islands	24,641	52,453
Other	387,048	457,463
Special naphthas	2,190	1,739
Lubricants	18	15
Wax	12	1
Asphalt	4,386	6,008
Unfinished oils, total	28,975	30,221
Receipts from Virgin Islands	9,564	9,661
Other	19,411	20,560
Total	572,922	681,716

a/ Includes some Athabasca hydrocarbons.
Source: See table 1.

Table 9. Tidewater Movements of Crude Oil and Products from the Gulf and West Coasts to the East Coast and from the Gulf Coast to the West Coast, 1969 and 1970

(In thousands of barrels)

Item	1969	1970
Gulf Coast to East Coast		
Crude oil	180,821	235,860
Unfinished oils	35,361	26,912
Gasoline, total	145,956	175,904
Motor	141,219	172,627
Aviation	4,737	3,277
Special naphthas	5,291	4,248
Kerosine	16,682	16,543
Distillate fuel oil	119,595	147,272
Residual fuel oil	27,326	28,514
Jet fuel, total	48,320	40,614
Naphtha-type	19,544	14,427
Kerosine-type	28,776	26,187
Lubricating oil	9,952	8,944
Wax	282	354
Asphalt and road oil	5,350	4,601
Liquefied gases	2,872	2,572
Petrochemical feedstocks	4,156	3,715
Other products	1,824	1,430
Total	603,788	697,483
West Coast to East Coast		
Crude oil	--	252
Unfinished oils	--	579
Gasoline, total	--	151
Motor	--	151
Aviation	--	--
Distillate fuel oil	--	--
Residual fuel oil	87	--
Jet fuel, total	--	40
Naphtha-type	--	--
Kerosine-type	--	40
Lubricating oil	755	894
Wax	3	5
Other products	--	25
Total	845	1,946
Gulf Coast to West Coast		
Crude oil	215	--
Gasoline, total	3,072	334

continued--

Table 9. Tidewater Movements of Crude Oil and Products from the Gulf and West Coasts to the East Coast and from the Gulf Coast to the West Coast, 1969 and 1970 continued--

(In thousands of barrels)

Item	1969	1970
Motor	2,630	334
Aviation	442	--
Special naphthas	91	39
Kerosine	2	92
Distillate fuel oil	1,461	18
Residual fuel oil	3	5
Jet fuel, total	6,551	2,454
Naphtha-type	3,741	774
Kerosine-type	2,810	1,680
Lubricating oil	1,375	--
Petrochemical feedstocks	195	100
Other products	--	80
Total	12,965	3,122

Source: See table 1.

Table 10. Barge Movements of Crude Oil and Products From PAD District III Via the Mississippi River to PAD Districts I and II, 1969 and 1970

(In thousands of barrels)

Item	1969	1970
District I		
Gasoline, total	13,777	15,461
Motor	13,587	15,294
Aviation	190	167
Special naphthas	244	220
Kerosine	1,458	1,541
Distillate fuel oil	2,318	2,373
Residual fuel oil	28	190
Jet fuel, total	774	757
Naphtha-type	--	--
Kerosine-type	774	757
Lubricating oil	1,909	2,159
Wax	2	31
Asphalt and road oil	--	--
Liquefied gases	--	--
Petrochemical feedstocks	659	433
Other products	201	65
Total	21,370	23,230
District II		
Crude oil	16,371	17,736
Unfinished oils	50	73
Gasoline, total	40,916	41,956
Motor	40,245	41,267
Aviation	671	689
Special naphthas	2,259	2,267
Kerosine	4,261	3,782
Distillate fuel oil	8,591	8,625
Residual fuel oil	5,724	7,785
Jet fuel, total	7,585	5,150
Naphtha-type	83	71
Kerosine-type	7,502	5,079
Lubricating oil	2,982	2,434
Wax	3	3
Asphalt and road oil	2,402	2,540
Liquefied gases	1,273	1,305
Petrochemical feedstocks	1,580	1,377
Other products	547	605
Total	94,544	95,638

Source: See table 1.

About one-third of the tidewater shipments from the gulf to the east coast is crude oil and nearly one-half is gasoline and distillate fuel oil. The remainder is scattered among a wide variety of products, with residual fuel oil accounting for less than 5 percent of the total.

IV. REGIONAL PATTERNS OF PETROLEUM CONSUMPTION AND WATERBORNE RECEIPTS WITHIN DISTRICT I

The relative concentration of demand for the principal petroleum products in the group of states north of the Carolinas is shown in table 11. These data are for 1968, the most recent year for which comparable data by state are available for all of the products shown: gasoline, distillate fuel oil, residual fuel oil, diesel oil, and kerosine. This group of products accounted for nearly 80 percent of total demand for petroleum products in the United States in 1968. The states north of the Carolinas accounted for 80 percent of consumption of these products in District I and for 36 percent of consumption in the United States.

However, the concentration is much greater for distillate and residual fuel oils (87 percent of District I consumption for each product group). These states accounted for 60 percent of U.S. residual fuel oil consumption in 1968. It is believed that this has increased both absolutely and relatively in subsequent years.

The pattern of petroleum receipts for 1968 at principal District I ports from foreign and U.S. coastal sources is shown in table 12. The distribution of crude imports and receipts by port conforms with the refinery location pattern discussed earlier. Of the total of 70.7 million net tons brought in for consumption in District I (imports of 21.5 million tons into Portland, Maine, are moved by pipeline to Canadian refineries), 67 million tons passed through the Port of New York and through ports on the Delaware River and Bay, with the latter accounting for over two-thirds of the total.

Table 11. Sales of Major Petroleum Products by State for PAD District I, 1968
(In thousands of barrels)

PAD District I States	Product					Total sales or consumption
	Gasoline consumption	All distillate oil sales	All residual fuel oil sales	Diesel oil sales	Kerosine sales	
Maine	10,316	10,647	8,590	745	2,285	32,583
New Hampshire	7,213	7,106	2,993	315	674	18,301
Vermont	4,555	5,058	547	239	900	11,299
Connecticut	26,408	21,748	28,433	1,896	722	79,207
Rhode Island	7,596	7,746	8,165	640	501	24,648
Massachusetts	45,156	56,315	68,586	2,509	1,921	174,487
New York	138,401	106,843	132,907	5,177	6,375	389,703
New Jersey	62,572	60,056	67,583	5,123	1,639	196,973
Pennsylvania	97,040	59,721	47,013	8,317	4,412	216,503
Delaware	5,776	3,918	4,357	374	596	15,021
Maryland	32,946	18,759	12,642	2,128	2,616	69,091
Virginia	45,011	22,286	14,701	4,199	6,650	92,847
West Virginia	15,120	3,743	1,984	1,464	351	22,662
District of Colombia	5,575	3,525	9,138	367	58	18,663
Subtotal	503,685	387,471	407,639	33,493	29,700	1,361,988
North Carolina	51,502	19,944	4,759	4,054	13,221	93,480
South Carolina	25,687	7,788	3,812	2,026	3,081	42,394
Georgia	48,285	12,013	8,725	5,405	520	74,948
Florida	67,320	14,794	40,543	4,305	3,453	130,415
Subtotal	192,794	54,539	57,839	15,790	20,275	341,237
Total PAD District I	696,479	442,010	465,478	49,283	49,975	1,703,225
U.S. total	2,009,928	873,100	669,484	171,773	103,110	3,827,395

Source: American Petroleum Institute, Petroleum Facts and Figures, 1971 ed. (Washington, D.C., 1971).

Table 12. Summary of Foreign Trade and Intercoastal Movements of Crude Petroleum and Products by North Atlantic Ports and Port Areas, 1968

(In millions of net tons)

Port or port area	Crude			Residual fuel oil			Other products[a/]		
	Imports	Coastal rects.	Total	Imports	Coastal rects.	Total	Imports	Coastal rects.	Total
Portland, Maine..	21.5[b/]	--	21.5	1.1	0.4	1.5	a/	3.2	3.2
Other Maine and New Hampshire..	--	--	--	1.6	a/	1.6	0.1	1.8	1.9
Boston, Mass.....	0.1	a/	0.1	6.6	0.2	6.8	0.2	9.6	9.8
Other Mass......	--	--	--	1.2	0.2	1.4	0.1	2.1	2.2
New Haven, Conn.	--	--	--	2.2	0.5	2.7	0.1	5.1	5.2
Other Conn. and Rhode Island...	--	0.3	0.3	2.9	2.6	5.5	a/	9.1	9.1
New York, N.Y...	10.5	8.1	18.6	25.6	1.5	27.1	4.2	7.8	12.0
Other New York..	--	--	--	1.2	0.4	1.6	--	4.5	4.5
Delaware River, Trenton, N.J. to the sea (inc. the Schuylkill River).........	26.6	21.8	48.4	6.7	1.1	7.8	0.2	3.9	4.1
Baltimore, Md...	0.5	0.1	0.6	2.8	0.2	3.0	0.2	2.1	2.3
Hampton Roads and York River, Va............	2.2	0.2	2.4	2.2	0.1	2.3	0.1	1.2	1.3
North Carolina..	0.1	--	0.1	0.5	a/	0.5	a/	1.6	1.6
South Carolina..	--	--	--	1.3	a/	1.3	a/	1.6	1.6
Georgia.........	a/	0.2	0.2	0.6	0.1	0.7	a/	0.7	0.7
Florida.........	a/	--	--	5.1	0.7	5.8	0.3	6.7	7.0
Total.........	61.5	30.7	92.2	61.6	8.0	69.6	5.5	61.0	66.5

a/ Gasoline, kerosine, and distillate fuel oil.
b/ Transit traffic to Canadian refineries.
Source: U.S. Department of the Army, Corps of Engineers, Waterborne Commerce of the U.S., Part 1, Waterways and Harbors: Atlantic Coast, 1968.

The greatest degree of concentration of imports and coastal receipts of residual fuel oil and other petroleum products was at the Port of New York (39.1 million tons of a total of 136.1 million tons). The distribution of the remaining nearly 100 million tons was spread among a large number of ports, reflecting the geographical characteristics of the consumption and distribution of these products.

V. U.S. PETROLEUM SUPPLY AND DEMAND PROJECTIONS

Introduction

For purposes of the deepwater port study it is necessary to project the volume of waterborne receipts of petroleum for the years 1980 and 2000 into the major coastal regions of the United States. These projections must differentiate between crude petroleum, residual fuel oil, and other refined products, because the origin, transportation, handling, and distribution characteristics are unique for each of these three categories.

Projection of waterborne receipts requires the development of estimates or assumptions of the demand and supply of crude petroleum and petroleum products on an aggregate basis for the United States, as well as by region. Specifically, one must estimate production of and demand for crude petroleum and petroleum liquids from other sources; production of and demand for refined products, distinguishing among residual fuel oil and other products; and interdistrict transfers and external sources of supply for each of the three petroleum categories.

A critical variable for which an estimate or assumption must also be made is the location of the refinery capacity within the United States required to supply internal demand for petroleum products, and the relative balance of such requirements between locations in the United States and overseas.

The appendix contains summary review of studies made by a number of private and public institutions during the past decade on the future supply and demand for petroleum in the United States. While all of these studies have quantitative projections (in some cases as far as the year 2000) of aggregate demand for petroleum, only a few address themselves to the question of internal and external sources of supply, and none of them attempt to answer the questions of regional demand and supply and the location of future increments in required refinery capacity.1/ However, these studies, supplemented by our own independent studies, provide a general framework for analysis and evaluation of the quantitative aspects of U.S. supply and demand for petroleum and for the identification of related issues. Among the most important of these issues are the following:

1. Does the United States have the basic resource and productive capabilities to avoid a substantial dependence on overseas sources of supply for crude petroleum?

2. To what extent could such capabilities be more fully realized through appropriate Federal Government policies related to crude petroleum prices, exploration, and import controls?

3. How much of the additional petroleum refinery capacity required to meet the incremental growth in U.S. demand, particularly in District I, will be constructed in District I, on the gulf coast, and at other possible locations, including offshore?

4. Will long-range worldwide petroleum supply constraints and increasing emphasis on air pollution control result in technological changes in the supply of

1/ With the exception of the National Petroleum Council study, which projects petroleum product demand by district, and estimates supply sources for District V for 1975, 1980 and 1985 (National Petroleum Council, U.S. Energy Outlook: An Initial Appraisal 1971-85, Interim Report Prepared by the National Petroleum Council's Committee on U.S. Energy Outlook [Washington, D.C., 1971], vol. 2, Summaries of Task Group Reports [November 1971]).

motive power to transport vehicles, and in the conversion of energy to electric power, that would bring about a decline in the long-term annual petroleum consumption growth rate from historical levels?

The treatment of these issues in connection with our own projections of petroleum demand and supply is discussed below. Our projections for the United States and for the five PAD districts are given in tables 13, 14, 15 and 16. For convenience, the data and projections for Districts II, III and IV are combined.

Demand for Crude Petroleum and Petroleum Products

Aggregate U.S. demand for petroleum products is estimated at 22.7 million and 35.0 million barrels daily in 1980 and 2000, respectively. The 1980 estimate corresponds with that given in the July 1971 study of the National Petroleum Council (NPC).1/ The year 2000 estimate is about 7 percent higher than the June 1971 estimate of the Secretary of Interior.2/ The implied growth rate for the period 1970-80 is 4.4 percent annually, and for the period 1980-2000, 2.2 percent annually.

The growth rate for the earlier period of 4.4 percent annually compares with an actual average of 4.1 percent during the preceding decade, but is somewhat below the average of 4.7 percent during 1968-70. The sharp increase during that 3-year period over 4.0 percent during 1960-68 was primarily due to the substitution of fuel oil for the consumption of natural gas and high-sulfur coal, supplies of natural gas and low-sulfur coal being inadequate. These influences are expected to continue to operate during the coming decade and are

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1/ National Petroleum Council, U.S. Enery Outlook: An Initial Appraisal 1971-85, Interim Report Prepared by the National Petroleum Council's Committee on U.S. Energy Outlook (Washington, D.C., 1971, vol. 1, Summaries of Task Group Reports [July 1971]).
2/ Statement of the Secretary of the Interior before

the prime reason for the higher than normal growth rate anticipated during that period.

Beyond 1980 a decline in the growth rate is forecast, reflecting the combined effects of the anticipated solution of the technical and economic problems which presently limit the use of high-sulfur coals for power generation; the rapidly increasing displacement of all fossil fuels by nuclear energy for the generation of electrical power; the development of new technology for the supply of motive power to transport vehicles; and the beginnings of the development of wholly new sources of energy, such as fusion.

The differential impact of these influences on demand for residual fuel oil and other products is reflected in the projections. Consumption of residual fuel oil is expected to nearly double from 1970 to 1980, and to stabilize at the 1980 level through the year 2000. On the other hand, the consumption of other petroleum products is expected to increase by less than 50 percent from 1970 to 1980, and by about 65 percent from 1980 to 2000.

For 1980 the demand for petroleum products by PAD districts is as estimated by the Oil Demand Task Group of the NPC's Committee on U.S. Energy Outlook.1/ For 2000, the distribution of petroleum product demand by district was modified somewhat from the 1980 distribution to reflect anticipated geographical shifts in population and income. Thus, the shares of the East and Midwest States decline, while those of the Southwest and Far West increase.

The aggregate demand for crude petroleum is, first, a function of total product demand, and second, of refinery output in the United States. For reasons

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the Committee on Interior and Insular Affairs, United States Senate, June 15, 1971.

1/ National Petroleum Council, op.cit., vol 2.

Table 13. Petroleum Demand/Supply Projections - U.S. Total

(In thousands of barrels daily)

Demand/ supply	1970				1980				2000			
		Products				Products				Products		
	Crude	Residual	Other	Total	Crude	Residual	Other	Total	Crude	Residual	Other	Total
Demand......	11,412[a/]	2,204	12,512	14,716	18,700[a/]	4,100	18,600	22,700	32,700[a/]	4,100	30,900	35,000
Production..	10,171	705	12,311	13,016[b/]	11,800	1,100	17,600	18,700[b/]	13,000	1,800	30,900	32,700[b/]
Surplus or (deficit)..	(1,241)	(1,499)	(201)	(1,700)	(6,900)	(3,000)	(1,000)	(4,000)	(19,700)	(2,300)	--	(2,300)
Exports.....	14	54	190	244	--	--	--	--	--	--	--	--
Imports from:												
Canada.....	672	--	--	--	1,900	--	--	--	2,500	--	--	--
L.A.- Carib.....	291	--	--	--	--	3,000	900	3,900	--	2,300	--	2,300
M.E.- Africa....	291	--	--	--	4,900	--	--	--	15,400	--	--	--
Far East...	70	--	--	--	100	--	100	100	1,800	--	--	--
Total.....	1,324	1,528	452	1,980	6,900	3,000	1,000	4,000	19,700	2,300	--	2,300
In million short tons....	74.3	[illegible]	25.4	111.2	387.5	168.5	56.2	224.6	1,106.2	129.2	--	129.2

a/ Runs to stills of crude and natural gasoline.
b/ Refinery output plus natural gas liquids (NGL) blended and produced at refinery.

Source: 1970 -- U.S. Department of the Interior, Bureau of Mines, Mineral Industry Surveys, "Monthly Petroleum Statement," December 1970, prepared by the Division of Fossil Fuels, March 23, 1970. 1980 and 2000 -- RRNA.

Table 14. Petroleum Demand/Supply Projections - PAD District I
(In thousands of barrels daily)

Demand/ supply	1970				1980				2000			
		Products				Products				Products		
	Crude	Residual	Other	Total	Crude	Residual	Other	Total	Crude	Residual	Other	Total
Demand......	1,300 a/	1,635	4,218	5,853	2,000 a/	3,150	6,050	9,200	4,000 a/	2,800	10,500	13,300
Production..	38	96	1,420	1,516 b/	50	150	1,850	2,000 b/	--	200	3,800	4,000 b/
Surplus or (deficit)..	(1,262)	(1,539)	(2,798)	(4,337)	(1,950)	(3,000)	(4,200)	(7,200)	(4,000)	(2,600)	(6,700)	(9,300)
Exports.....	--	2	19	21	--	--	--	--	--	--	--	--
Domestic shipments to Dist. II	--	--	120	120	--	--	200	200	--	--	300	300
Total.....	--	--	120	120	--	--	200	200	--	--	300	300
Domestic rects. from District:												
II.........	21	--	54	54	--	--	--	--	--	--	--	--
III........	652	78	2,617	2,695	--	--	3,530	3,530	--	300	7,000	7,300
IV.........	10	--	--	--	--	--	--	--	--	--	--	--
V..........	1	--	2	2	--	--	--	--	--	--	--	--
Total.....	684	78	2,673	2,751	--	--	3,530	3,530	--	300	7,000	7,300
Imports from:												
Canada.....	86				--	--	--	--	--	--		
L.A.-Carib.	268				--	3,000	870	3,870	--	2,300		
M.E.-Africa	225				1,950	--	--	--	4,000	--		
Far East...	--				--	--	--	--	--	--		
Total.....	579	1,471	314	1,785	1,950	3,000	870	3,870	4,000	2,300	--	2,300
In million short tons....	32.5	82.6	17.6	100.2	109.5	168.5	48.9	217.3	224.6	129.2	--	129.2

a/ Runs to stills of crude and natural gasoline.
b/ Refinery output plus NGL blended and produced at refinery.
Source: See table 13.

Table 15. Petroleum Demand/Supply Projections - PAD Districts II, III and IV
(In thousands of barrels daily)

Demand/ supply	1970				1980				2000			
		Products				Products				Products		
	Crude	Residual	Other	Total	Crude	Residual	Other	Total	Crude	Residual	Other	Total
Demand......	8,355 a/	311	6,598	6,909	13,900 a/	600	9,800	10,400	23,200 a/	800	15,400	16,200
Production..	8,848	362	9,336	9,698 b/	8,600	600	13,300 b/	13,900	10,000	1,100	22,100	23,200 b/
Surplus or (deficit)..	493	51	2,738	2,789	(5,300)	--	3,500	3,500	(13,200)	300	6,700	7,000
Exports.....	13	13	95	108	--	--	--	--	--	--	--	--
Domestic shipments to Dist:												
I..........	680	78	2,671	2,749	--	--	3,530	3,530	--	300	7,000	7,300
V..........	38	--	154	154	--	--	170	170	--	--	--	--
Total.....	718	78	2,825	2,903	--	--	3,700	3,700	--	300	7,000	7,300
Domestic rects. from District:												
I..........	--	--	120	120	--	--	200	200	--	--	300	300
V..........	--	--	--	--	570	--	--	--	--	--	--	--
Total.....	--	--	120	120	570	--	200	200	--	--	300	300
Imports from:												
Canada.....	365				1,700	--	--	--	2,300			
L.A.-Carib.	--				--	--	--	--	--			
M.E.-Africa	--				3,030	--	--	--	10,900			
Far East...	--				--	--	--	--	--			
Total.....	365	42	71	113	4,730	--	--	--	13,200			
In million short tons....	20.5	2.4	4.0	6.3	265.6				741.2			

a/ Runs to stills of crude and natural gasoline.
b/ Refinery output plus NGL blended and produced at refinery.

Source: See table 13.

Table 16. Petroleum Demand/Supply Projections - PAD District V
(In thousands of barrels daily)

Demand/ supply	1970				1980				2000			
		Products				Products				Products		
	Crude	Residual	Other	Total	Crude	Residual	Other	Total	Crude	Residual	Other	Total
Demand......	1,710[a/]	258	1,696	1,954	2,800	350	2,750	3,100	5,500[a/]	500	5,000	5,500
Production..	1,285	247	1,555	1,802[b/]	3,150	350	2,450	2,800[b/]	3,000	500	5,000	5,500[b/]
Surplus or (deficit)..	(425)	11	141	152	350	--	(300)	(300)	(2,500)	--	--	--
Exports.....	--	39	76	115	--	--	--	--	--	--	--	--
Domestic shipments to Dist. II	1	--	22	22	570	--	--	--	--	--	--	--
Total.....	1	--	22	22	570	--	--	--	--	--	--	--
Domestic rects. from District:												
III........	8	--	60	60	--	--	--	--	--	--	--	--
IV.........	31	--	94	94	--	--	170	170	--	--	--	--
Total.....	39	--	154	154	--	--	170	170	--	--	--	--
Imports from:												
Canada.....	220				200	--	--	--	200	--	--	--
L.A.-Carib.	23				--	--	--	--	--	--	--	--
M.E.-Africa	66				--	--	--	--	500	--	--	--
Far East...	70				20		130	130	1,800	--	--	--
Total.....	380	15	67	82	220		130	130	2,500	--	--	--
In million short tons....	21.3	.8	3.8	4.6	12.4		7.3	7.3	140.4			

a/ Runs to stills of crude and natural gasoline.
b/ Refinery output plus NGL blended and produced at refinery.
Source: See table 13.

that will be explained in the discussion of refined product output, our estimates of crude petroleum demand are 18.7 million barrels daily in 1980 and 32.7 million barrels daily in 2000. No downward adjustment in the demand for crude is made to reflect the relatively insignificant gain in product volume resulting from the refinery processing of the crude.

The Supply of Petroleum and Products

U.S. Production and Deficits

The U.S. production of crude petroleum (including natural gas liquids) for 1980 is as shown in the NPC energy outlook study. The breakdown by district is derived from the NPC Oil Logistics Task Group report. Of the total of 11.8 million barrels daily, 2.0 million are assumed to be from the North Slope of Alaska, and the balance from the lower 48 states. There is no assumed production of synthetic oil from shale or from coal. Crude petroleum production in the lower 48 states in the NPC report shows a constant decline from 9.6 million barrels daily in 1970 to 8.1 million in 1985.

The NPC explicitly stated that its projections do not represent a probable forecast of the future. Rather, they are an estimate of future production trends, assuming no change in present U.S. Government policies with respect to petroleum prices and other incentives to petroleum exploration and development, and to the development of oil from coal and shale. In referring to its projected supply-demand forecast for the Western Hemisphere, which estimates an overall Western Hemisphere daily import requirement of 6.7 million barrels in 1980 and 10.6 million in 1985, the Oil Supply Task Group made the following observation:

> Any interpretation of this balance must recognize that the liquid hydrocarbon supply projections are conservatively biased, as they project recent finding and development trends that are generally

> unfavorable; current price levels that are most likely to change upward, and existing government policies that are also likely to change, hopefully with constructive and positive impact on oil industry incentives.1/

The NPC projection of a declining trend in crude oil production in the lower 48 states is amply documented by reference to historical trends in crude petroleum exploration, discoveries, and reserve ratios. It was considered appropriate to use the NPC projection for 1980 as representing the most informed judgment available on the prospects for production, given a continuation of existing policies. Both industry and Government were widely represented in the task groups, committees, and subcommittees which prepared the study. The impact of possible future policies designed to improve economic incentives for the development of the production of petroleum liquids in the United States would be gradual. Unless such policies were instituted soon, they would not have a quantitative significance by 1980.

Our estimate for the year 2000 of 13.0 million barrels daily production of petroleum liquids assumes a turnaround in the downward trend, and the evolution of an economic and policy framework conducive to increased production of crude petroleum and of oil from coal and shale.

The deficit in crude petroleum would be 6.9 million barrels daily in 1980 and 19.7 million in 2000, compared with 1.2 million in 1970. Regionally, the growth in the deficit in District I is constrained by the assumptions as to refinery location, which are discussed below. Districts II, III and IV, which had a combined surplus of nearly 0.5 million barrels daily in 1970, would have a deficit of 5.3 million barrels daily in 1980 and 13.2 million in 2000. With production of 2

1/ National Petroleum Council, op.cit., vol 2, 52-53.

million barrels daily of Alaskan crude, District V would have a surplus in 1980; by the year 2000, however, it would have a deficit of 2.5 million barrels daily.

Projections of the output of refined products in the aggregate reflect an assumption that refinery capacity will basically be equal to the demand for products, with the exception of the imbalance in the supply of and demand for residual fuel oil. This imbalance is the result of the rapid growth in demand for residual discussed earlier, and the relatively small margin of residual output from U.S. refineries (6.2 percent in 1970). Historically, conditions of competition from other fuels in the residual fuel oil market dictated the minimization of residual output and the maximization of output of other petroleum products. Most existing refinery capacity is designed to achieve this objective. It is understood that there is not much scope for significantly altering the residual share of output from existing refineries, even if there were an economic incentive to do so.1/

The projected output of residual fuel oil assumes a continuation of its present share of U.S. refinery output, with the resulting deficit to be met principally from refineries now in existence or to be constructed at offshore locations, principally in the Caribbean. These would utilize technology and crude petroleum sources designed to maximize output of low-sulfur residual fuel oil for the U.S. market. In 1980 these refineries would also have a surplus of other products for export to the U.S. By 2000 these other products would be exported to markets in Latin America, even though there continued to be a market for residual fuel oil in the United States.

Of total refinery capacity and output in the United States in 1980, it is assumed that a capacity of

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1/ However, proposals have been made by independent interests for the construction of new type processing plants which would provide pipeline quality gas and optimize residual fuel oil output.

2 million barrels daily (MBD) will be located in PAD District I (virtually all in the states north of the Carolinas). District V would be virtually self-sufficient in refining capacity, and Districts II, III, and IV combined would have sufficient capacity to meet their own requirements and to supply the deficit in District I for products other than residual fuel oil. The assumptions are essentially the same for 2000, except that in District I there would be an increase of refinery capacity to 4 million barrels daily.1/

Aggregate residual fuel oil import levels would be 3 million and 2.3 million barrels daily in 1980 and 2000, respectively, all of which would be imported into District I. Imports of other products would be 1 million barrels daily in 1980, of which 870,000 would go to District I and 130,000 to District V.

Foreign Sources of Supply

The allocation of crude petroleum import requirements among foreign sources in the projections conforms to the broad conclusion that only the oil-producing nations of the Middle East and Africa have sufficient reserve and productive capacity to supply the bulk of the anticipated U.S. demand for petroleum from external sources of supply. Of the total crude deficit of 6.9 million barrels daily in 1980, 4.9 million are shown as coming from Middle East and African sources, 1.9 million from Canada, and 100,000 from the Far East. The Canadian crude would go to Districts II and V, and the Far East crude to District V. Middle East-African crude would go to Districts I and III, and possibly also to District II. It is assumed that the petroleum surplus of Venezuela and other Latin American producers would be refined mainly in the Caribbean area and shipped to the United States as refined products, principally residual fuel oil.

1/ In view of the uncertainty as to future location of refinery capacity to meet east coast needs, the crude petroleum impact throughout our deepwater port alternative on the North Atlantic and gulf coasts, were based on alternative assumptions of east coast refinery capacity of 2 and 3 MBD in 1980, and 3 and 6 MBD in 2000.

For 2000, when crude import requirements would be 19.7 million barrels daily, the supply sources are basically the same, with virtually all of the growth in demand from external sources coming from Middle East-Africa and the Far East.

The indicated level of imports from Canada assumes the discovery and development of new petroleum resources in the far northern frontier areas of Canada, where considerable exploration activities are underway and indications are favorable for the discovery of commercial petroleum deposits. They also assume Canadian Government policies favorable to the development of such resources as a source of supply for the United States.

Prospective supplies from Latin America are dominated by the position of Venezuela, which has over half of the proved petroleum reserves and over 70 percent of crude petroleum production in the Western Hemisphere outside of the United States and Canada (table 17).

The NPC Oil Supply Task Group projected a decline in Latin American and Venezuelan crude oil production after 1980. It attributed this to the continued emphasis by the Venezuelan Government on the need to conserve its oil reserves to meet domestic requirements, and to the fact that major contract concession arrangements for the exploration and development of petroleum resources with the Venezuelan Government will terminate in the early 1980's. Uncertainty about the terms of the service contracts which will take the place of the present concession arrangements adversely affects the prospects for any significant growth in productive capacity.

As shown in table 17, the Middle East and African countries have 419 billion barrels of total proved free world petroleum reserves of 511 billion barrels. By comparison, the U.S. proved reserves are 37 billion barrels. Within the Middle East and African areas, the dominant countries in both petroleum reserves and production are Iran, Iraq, Kuwait, Saudi Arabia, Algeria, and Libya. The relative lag of the United States in

Table 17. World Petroleum Reserves and Production, 1970
(In thousands of barrels)

Country	Proved reserves	Estimated 1970 daily production
Total Europe	3,708,500	356.4
Asia-Pacific		
Afghanistan	95,000[a]	46.8[a]
Australia	2,000,000	170.1
Brunei-Malaysia	1,000,000	146.2
Burma	40,000	15.6
India	956,000	139.0
Indonesia	10,000,000	861.2
Japan	30,000	16.3
New Zealand	226,000[a]	.06
Pakistan	41,500	9.8
Taiwan	20,000	1.7
Thailand	148	0.3
Total	14,408,648	1,407.1
Middle East		
Abu Dhabi	11,800,000	640.9
Bahrain	634,000	76.8
Dubai	983,000	77.9
Iran	70,000,000	3,753.2
Iraq	32,000,000	1,517.8
Israel	12,900	93.0[b]
Kuwait	67,100,000	2,743.8
Neutral Zone	25,700,000	485.6
Oman	1,700,000	336.1
Qatar	4,300,000	353.9
Saudi Arabia	128,500,000	3,437.5
Syria	1,200,000	50.0
Turkey	645,000	68.0
Total	344,574,900	13,634.5
Africa		
Algeria	30,000,000[c]	984.0
Angola (including Cabinda)	500,000	110.0
Congo-Brazzaville	3,600	0.5
Congo-Kinshasa	1,000[d]	--
Dahomey	1,000[d]	--
Egypt	4,500,000	328.5
Gabon	700,000	106.0

continued--

Table 17. World Petroleum Reserves and Production, 1970 continued--

(In thousands of barrels)

Country	Proved reserves	Estimated 1970 daily production
Ghana	1,000[d/]	--
Libya	29,200,000	3,385.0
Morocco	920	1.0
Nigeria	9,300,000	1,000.0
Tunisia	550,000	88.0
Total	74,757,520	6,003.0
Western Hemisphere		
Argentina	4,500,000	391.0
Barbados	750[d/]	--
Bolivia	225,000	13.2
Brazil	850,000	157.6
Chile	125,000	38.3
Colombia	1,675,000	222.0
Cuba	14,000	2.5
Ecuador	750,000	4.0
Honduras	500[d/]	--
Mexico	3,200,000	427.4
Peru	270,000	72.0
Trinidad and Tobago	575,000	141.0
Venezuela	14,000,000	3,690.0
United States	37,012,640	9,506.5
Canada	10,750,000	1,277.5
Total	73,947,890	15,943.0
Total free world	511,397,458	37,344.0
Communist world	100,000,000[e/]	7,566.0
Total	611,397,458	44,910.0

a/ Condensate.
b/ Includes captured Sinai fields.
c/ Government estimate.
d/ Oil or gas discovered but not yet developed.
e/ Including U.S.S.R., 77 billion; People's Republic of China, 20 billion; Hungary, 1 billion; others, 2 billion.

Source: National Petroleum Council, U.S. Energy Outlook: An Initial Appraisal 1971-1985, Interim Report Prepared by the National Petroleum Council's Committee on U.S. Energy Outlook vol. 2, Summaries of Task Group Reports (Washington, D.C., November 1971), table 37.

the development of additions to proved oil reserves in the period 1955-70, and the inadequacy of that historical performance when related to anticipated consumption requirements in the next 15 years, is demonstrated by the NPC Oil Supply Task Group.1/

Of total additions to proved reserves in the free world during 1955-70 of 450 billion barrels, only 42.7 billion were in the United States. These additions to U.S. reserves compare with an estimated U.S. oil demand during the next 15 years of 110.6 billion barrels. Additions of 407 billion barrels in other free world countries compare with an estimated consumption demand in those countries during 1971-85 of 241 billion barrels. Thus, for the next 15-year period at least, the other free world countries are in a comfortable surplus position. But the aggregate free world demand during the 1971-85 period of 352 billion barrels, compared with total reserve additions during 1955-70 of 450 billion barrels, suggests a tight overall supply-demand situation in the free world, unless the total additions to reserves in the next 15 years should be greater than during the past 15 years. Thus the possibility of constraints on free world petroleum supplies exercising a limiting role on growth in the consumption of petroleum products in the period 1985-2000 is clearly foreshadowed.

1/ National Petroleum Council, op. cit., vol 2. Chapter 3.

VI. SENSITIVITY ANALYSIS OF THE PETROLEUM PROJECTIONS

U.S. Demand

The 1980 estimate of demand for petroleum products in the United States may be regarded as reasonable. It could be high if there should be a turnaround in the rate of discovery of natural gas reserves and a consequent better balance between the supply of and demand for natural gas than is presently assumed and anticipated by the petroleum and natural gas industries. However, the impact of such a development would be felt principally in the demand for residual fuel oil. It would not affect significantly the requirements for other refined products or for crude petroleum for refining in the United States. Other than this, it is considered highly unlikely that any basic shift in the pattern of petroleum product demand growth during the next decade could have a significant quantitative impact on levels of demand by 1980.

On the other hand, the estimated demand for petroleum products in the year 2000 assumes the initiation of such shifts and a very significant quantitative impact by that year. If petroleum resources available to the United States internally and from other sources are adequate to sustain higher levels of consumption at competitive prices with alternative sources of energy, and if a decline in the growth of petroleum consumption is not brought about as the result of social controls and technological developments, the estimated level of consumption for 2000 may be regarded as conservative. Thus the estimate is somewhat more speculative. But it does appear reasonable to anticipate, on the basis of

what is presently known, that a long-term decline in the annual growth of petroleum product consumption in the United States will begin between 1980 and 2000.

U.S. Production

The estimates of U.S. production of petroleum liquids for both 1980 and 2000 may be considered conservative, taking into account the basic resource position of the United States in petroleum and coal, and the possibility that the U.S. Government may at some time in the near future adopt policies more conducive to the development and production of indigenous resources. As shown in table 18, as of January 1966 discoveries of crude petroleum in the United States equaled 386 billion barrels of a total estimated discoverable resource of 1,000 billion barrels. The undiscovered discoverable petroleum resources of the United States of over 600 billion barrels are the largest in the free world, with the exception of Africa. They should be compared with a total indicated production during the period 1970-2000 of approximately 130 billion barrels at the output levels indicated in our projections.

Thus the position with respect to potential petroleum resources, and the even greater availability of reserves of shale and coal from which petroleum liquids may be recovered, suggests the possibility that indigenous production of petroleum liquids may be somewhat greater in 1980, and significantly greater in 2000, than estimated. However, such higher levels of production in the United States in 2000 may be offset by higher levels of consumption, so that volumes of crude petroleum imports may not differ significantly from those indicated in the projections.

The output of refined products in the United States is subject to uncertainties which could result in levels either higher or lower than those indicated in the projections. Generally speaking, the economics of the industry favor the refining of petroleum products near the point of consumption. This is

Table 18. World Crude Oil-in-Place Discoverable and Discovered
(In billions of barrels)

Country	Existing[a/]	Discoverable[b/]	Discovered 1-1-62[c/]	Discovered 1-1-66[d/]
Western Hemisphere				
U.S.	1,600	1,000	346	386
Canada, Mexico, Central America, and Caribbean	500	300	50	77
South America (including Venezuela	800	500	214	238
Subtotal	2,900	1,800	610	701
Eastern Hemisphere				
Europe	500	300	21	26
Africa	1,800	1,100	56	139
Middle East (excluding Turkey)	1,400	900	793	928
South Asia	200	100	7	8
U.S.S.R., China, Mongolia	2,900	1,800	90	122
Indonesia, Australia, etc.	300	200	21	25
Subtotal	7,100	4,400	988	1,248
Total	10,000	6,200	1,598	1,949

a/ Total oil-in-place (Hendricks, 1965).
b/ Total discoverable oil-in-place (Hendricks, 1965).
c/ Original oil-in-place in known reservoirs as at 1-1-62 (Torrey, Moore and Weber, 1963).
d/ Hypothetical calculation of original oil-in-place in reservoirs as known at 1-1-66 (D.C. Ion, 1967).

Source: See table 17.

particularly true where the crude petroleum must be transported over long distances, as would be the case for most of the requirements of District I and a significant portion of the requirements of Districts II and III. Thus economic considerations would accord with the assumption in our projections that the United States would be virtually self-sufficient in refining capacity for products other than residual fuel oil. These considerations also suggest that a much larger share of the petroleum product requirements of District I would be supplied from refineries in the district than is assumed in our projections.

However, important influences are at work which are presently resulting in the construction of refining capacity at offshore locations, largely or exclusively geared to the petroleum markets for residual fuel oil as well as other products in District I. These influences make it difficult to project realistically the installation of substantial refining capacity at new locations in the Middle and North Atlantic States in District I. Thus, the increase to 2 million barrels daily in 1980 and 4 million barrels daily in 2000 may be somewhat high, and the dependence of District I on imports of petroleum products from foreign sources or from refineries on the gulf coast may be higher than in the projections. The forces referred to are the following:

1. The availability of deepwater ports at such nearby locations as the Maritime Provinces of New Brunswick, Newfoundland and Nova Scotia in Canada, and at certain islands in the Caribbean. Such refineries owned by U.S. companies are already in operation in Nova Scotia, the Grand Bahamas, Puerto Rico, and the Virgin Islands. In addition, the construction of a deepwater tanker terminal and refinery has been announced for Newfoundland, and a similar terminal, with the possibility of a refinery, has been announced for New Brunswick.

2. Environmental and ecological considerations are an obstacle to the installation of refining capacity at new locations in District I. Within the past several years the States of Maine and Delaware have acted to deny applications by petroleum companies to construct refinery capacity at new locations. Similar

action has been taken at the local level in several states, including Rhode Island.

3. The operations of the import controls system have encouraged the construction of residual fuel oil refining capacity outside the United States. Under the system, imports of foreign crude oil are subject to quota limitations, whereas in the past 4 or 5 years residual fuel oil has been permitted to enter District I without quota limitations.

The NPC Oil Logistics Task Group observes that the last new refineries built on the east coast were completed in 1957, prior to the imposition of mandatory import controls in 1959; that no substantial net additions to crude throughput capacity in existing plants have been made in more than a decade; and that no new refinery capacity is currently in the construction stage.

The assumption that a substantial proportion of District I refined product requirements would be supplied from refineries on the gulf coast in District III reflects the judgment that this may be the only practicable alternative available to the petroleum companies, even though it would be less economic than supplying these products from refineries in District I. Over 3 million barrels daily of refinery capacity are already concentrated in the Houston-Port Arthur-gulf coast area of Texas. These refineries and refineries in Louisiana are already supplying nearly 3 million barrels daily of products to District I, most of it by pipelines, whose capacities are being expanded. Ecological and environmental considerations are not expected to be an obstacle to the installation of additional refinery capacity in the Texas-gulf coast area as they are in District I.

Furthermore, provided deepwater port facilities are made available, the location of refineries on the gulf coast may have economic and other advantages over the alternative of location in the Maritime Provinces of Canada or in the Caribbean.

One of these advantages is the relatively greater flexibility of access by gulf coast refineries to crude petroleum from both foreign and domestic sources, with the possibility of quick and low cost adaptation to shifts in sources dictated by changes in conditions of supply.

Thus, it would appear that the levels of imports of petroleum products other than residual fuel oil, particularly into District I, may be somewhat higher than indicated in the projections, with consequent reductions in aggregate U.S. refinery output and related demands for crude petroleum in Districts I and III. For the reasons stated, however, it is not believed that this deviation from the projections would be quantitatively significant, given the provision already made for imports of 900,000 barrels daily of other products by 1980. The major uncertainty, therefore, pertains to the distribution of refining capacity between the gulf and East Coasts required to meet the needs of District I.

The source of imports of foreign crude would be sensitive principally to wholly unpredictable developments which might affect the availability of Middle East and African crude oil to the United States, or which might increase the availability of supplies from other sources. From what is known about the relative resource position of the Middle East and African oil-producing countries, and the constraints on supplies from other sources, the allocation of imports by region as shown in projections may be regarded as reasonable. This is further reinforced by the data in table 19 showing that 90 percent of the proved crude oil reserves of the seven leading international petroleum companies are in the Eastern Hemisphere.

Table 19. World Crude Oil Reserves by the Seven Major International Oil Companies, 1965

(In millions of tons)

Company	Total reserves a/	Eastern Hemisphere
British Petroleum	8,130	b/
Gulf Oil	5,900	5,450
Royal Dutch-Shell	3,850	2,840
Mobil Oil	2,300	2,150
Standard Oil of California	3,900	3,640
Standard Oil (New Jersey)	6,850	4,920
Texaco	4,050	3,500
Seven-company total	34,980	30,630
Others c/	9,056	4,040
World total, excluding Communist countries	44,036	34,670

a/ Estimates.
b/ Almost all BP's operations are concentrated in the Eastern Hemisphere.
c/ Obtained by subtracting the total for the seven companies from the world total (excluding Communist countries).

Source: Annual reports of the seven companies for all years; Petroleum Press Service, January 1966; BP, Statistical Review of the World Oil Industry, 1961-65; supplemented for reserves by ENI estimates based on The Oil and Gas Journal, end-of-year issue 1965.

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VII. INDICATED PHYSICAL AND LOCATIONAL CHARACTERISTICS OF PETROLEUM DEEPWATER PORT FACILITIES

The quantitative significance of the projections in terms of port requirements are apparent. As shown in tables 13 through 16, imports into District I in 1980 of crude petroleum and products would exceed 300 million short tons, with crude being more than 100 million tons, and residual fuel oil nearly 170 million tons. Imports of crude into Districts II, III, and IV would be 266 million tons, of which approximately 100 million tons would be overland receipts from Canada, with the balance being waterborne receipts from Middle East-African sources. By the year 2000, imports of crude petroleum into Districts I, II, III, and IV would approximate 1 billion short tons, of which 140 million would be from Canada and the balance from Middle East-African sources.

The projections for District V include the supply of 2 million barrels daily of Alaskan oil in 1980 and 2000, which presumably would move by tanker from Port Valdez to refinery centers in the Seattle, Los Angeles, and San Francisco areas. By 2000, District V would also have an import requirement from overseas sources of 2.5 million barrels daily, or roughly 140 million tons, all of which would come from either Middle East-African or Far Eastern sources, such as Indonesia.

As stated in chapter II and as shown in figure 2, the bulk of existing east coast refining capacity is concentrated in the northern New Jersey sector of the Metropolitan New York area, and in the Philadelphia-Camden area. The northern New Jersey refineries receive their crude by tanker through the Port of New York. All

of the other refineries are located along the Delaware Bay and River and receive their crude from tankers through that waterway. In the absence of any realistic basis for projecting expansion of refinery capacity at new locations on the east coast, it appears reasonable to assume that expansion will take place at existing locations. The capacity and locational characteristics of deepwater ports for the receipt and transfer of crude petroleum to refineries at these existing locations are governed by this assumption and by the further assumption that capacity increases in the two broad regional areas of refinery location will be in proportion to existing capacity.

The locational, capacity, and draft characteristics of ports needed to handle the imports of residual fuel oil into District I are not so clearly indicated. As shown in table 12, the destination points along the waterways for the delivery of residual fuel oil are much more diverse and less concentrated than they are for crude oil. Residual fuel oil is imported by distributors and is also imported directly by large consumers such as electrical generating companies and delivered directly to plants. The volume characteristics to any given point of delivery are considerably smaller than they are for a major refinery. The port and handling requirements are further complicated by the viscous nature of residual fuel oil, which makes it necessary to heat the oil when transferring it from tanker to delivery point, and likewise when moving it by pipeline. For these reasons residual fuel oil tends not be be moved by pipeline, as are crude petroleum and other petroleum products, and to be delivered by water directly to storage facilities at the point of consumption or distribution.

Another characteristic of the import of residual fuel oil is the expectation that the bulk of the supplies will be from refineries located either in the Caribbean area or possibly in the Maritime Provinces of Canada. Thus ocean transportation distances are relatively short when compared with the import of crude petroleum from the Middle East and Africa.

The volume of residual fuel oil imports may be reduced substantially by the proposed establishment of innovative refineries and processing plants in the United States designed to maximize the output of residual fuel oil and to produce pipeline-quality gas. This increase in the indigenous supply of residual fuel oil and natural gas would reduce the residual fuel oil import requirement proportionately. Plans are well advanced the construction of such a refinery in the Norfolk area to be located in a free trade zone, which would permit the import of crude petroleum and the distribution of the residual fuel oil and natural gas output without quota control.1/ Proposals for a similar plant at Baltimore Harbor have also been announced.2/

It is equally difficult to determine the capacity and design characteristics of possible deepwater port facilities to handle the receipt of other petroleum products from District III and from Caribbean sources. While projected receipts from District III at 3.5 million barrels daily, or approximately 200 million short tons annually, are very large, one is not able to estimate with any degree of confidence the proportion of this movement that would go by pipeline (as opposed to waterborne movement) directly to major consuming centers in the district. In 1970 over half of the petroleum product shipments from District III to District I were by pipeline.

Two major petroleum product pipeline systems carry products to District I from District III. The largest is the Colonial Pipeline Company, controlled by American Oil, Cities Service, Continental Oil, Mobile Oil, Phillips, Atlantic Richfield, Texaco, and Union Oil of California. It has a 36-inch trunk line from Houston to Greensboro, North Carolina; a 32-inch trunk line from Greensboro to the Dorsey Junction in Maryland; and a 30-inch line from Dorsey Junction to Linden, New Jersey. In addition, there are a number of smaller distribution lines throughout the service area of the pipeline. In

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1/ Mid-Atlantic Clean Energy Center, Inc., Washington, D.C.
2/ Washington Evening Star, January 26, 1972.

1970, the system delivered approximately 1.15 million barrels of products consisting of gasoline, kerosine, and distillate fuel oil.1/

Early in 1971 Colonial announced expansion plans for its system, including the construction of a 36-inch parallel line from Baton Rouge to Atlanta, Georgia, and the addition of a number of new intermediate pumping stations which would have the effect of increasing the capacity of the existing trunk lines.2/

Plantation Pipeline Company operates lines from Baton Rouge through Alabama, Georgia, Tennessee, South Carolina, North Carolina, and terminating in the Richmond, Virginia/Washington, D.C., area. In 1970 it handled an average of 440,000 barrels daily of gasoline, kerosine, and distillate fuel oil. The Plantation Pipeline Company is controlled by Humble Oil, Shell Oil, and Refiners Oil.3/

The existing predominance of pipeline movement over waterborne movement of so-called white petroleum products from the gulf coast area to District I, and the substantial expansion of the Colonial Pipeline System already underway, suggest that this is the preferred mode of transport for that movement. On a total distribution cost basis, this mode may be superior to waterborne coastal movement. Conceivably the existence of port facilities at both the gulf coast origin points and the east coast destination points, capable of handling tankers with greater capacity, could modify or even reverse any pipeline advantage. But it seems reasonably certain that the capacity of the existing pipeline systems and the expansion already under construction tion would be fully utilized for the useful life of the

1/ Annual Report of Colonial Pipeline Company, Altanta, Georgia, to the Interstate Commerce Commission for the year ended December 31, 1970.
2/ Colonial Pipeline Company Press Release of January 29, 1971, Atlanta, Georgia.
3/ Annual Report of Plantation Pipeline Company to the Interstate Commerce Commission for the year ended December 31, 1970.

equipment. The combined capacity of both systems may approximate 2.5 million barrels daily when the expansion is completed, or over 70 percent of the projected 1980 movement of petroleum products into District I from District III.

Part of this movement will consist of products other than gasoline, kerosine and distillate fuel oil that, because of their volume and distribution characteristics, do not lend themselves to pipeline transmission. But the same characteristics would make them less adaptable to movement by deep-draft tanker, if it were otherwise found that the use of such tankers would be competitive with the use of the pipeline.

Waterborne petroleum movements in the gulf area for which deepwater port requirements may firmly be established relate to the import of crude oil from Middle East and African sources either for refining on the gulf coast or for transshipment by pipeline or barge to refineries in the upper Midwest area. The bulk if not all of the requirement, particularly in 1980, would be for refining on the gulf coast. However, by 2000 perhaps as much as half would be required to fill the crude petroleum deficit of the Midwest area.

APPENDIX. REVIEW OF STUDIES OF PETROLEUM SUPPLY AND DEMAND IN THE UNITED STATES

Review of Demand Projections Prepared as of 1968

There have been a number of studies of future petroleum supply and demand in the United States by private and government sources. In some cases these have been as part of studies and projections of total energy supply and demand, and in some cases they have not. In December 1969, the Battelle Memorial Institute submitted a report to the Office of Science and Technology in the Executive Office of the President entitled, A Review and Comparison of Selected U.S. Energy Forecasts. Appendix table 1 is a summary of 12 such forecasts of total energy requirements expressed in trillions of B.t.u.'s.

All of these studies have projections for 1980, and several of them contain estimates for 1985 and 2000. There is a tendency for the more recent estimates to be higher than those prepared in earlier years. The range for 1980 is from 61.0 quadrillion B.t.u.'s in the 1962 report of the National Research Council to a high of 99.7 quadrillion B.t.u.'s in the unpublished thesis of Alan Strout prepared in 1968. The lowest projection for 1980 appearing in any of the studies prepared in 1968 was 88.1 quadrillion B.t.u.'s in the reports of the Office of Oil and Gas and of the Bureau of Mines of the Department of Interior.

Appendix table 2 shows the assumed or implicit annual growth rates applicable to the various forecast periods for the studies considered. There is

Appendix table 1. Forecasts of Total Energy Requirements
(In trillions of B.t.u.'s)

Source document	Date of publication	Base years	Base value	1970	1975	1980	1985	2000
CGAEM[a/] ..	1968	1947 to 1965	30,838 52,350	64,444	79,611	97,825	119,597	--
EUS[a,d/] ..	Sept. 1967	1960 to 1965	41,453 50,314	60,827	79,944	93,374	118,126	--
NF & ES..	Sept. 1962	1961	44,064	--	--	82,000[b/]	--	--
RAF......	Sept. 1962	1960	45,250	60,190	--	79,200	--	135,200
PEC......	Dec. 1962	1947 1962	33,168 47,897	--	--	85,934	--	--
ER.......	Dec. 1962	1907 to 1960	14,600 44,900	--	--	61,000 (min.)	--	--
OEUS.....	Oct. 1968	1950 to 1965	-- --	--	--	97,000[c/]	--	--
USP......	July 1968	1965	54,000	--	--	88,100	--	--
EMUS.....	July 1968	1947 to 1965	33,168 53,791	64,276	75,605	88,075 83,900[d/]	--	168,600 158,951[d/]
PCCP[d/] ...	May 1968	1948 to 1965	54,000	--	--	91,000	--	155,000
FFF......	Oct. 1960	1953	41,000	--	73,000	86,200	--	170,000
TCUSEC[e/] .	1968	1960	48,200	--	--	90,300 (99,700)	--	174,000 (213,000)

a/ Hydro accounted for at kwh energy equivalent.
b/ Consensus of 11 forecasts.
c/ Their 17,000 million barrels of oil equivalent are converted to B.t.u.'s at 5,800,000 B.t.u.'s per barrel.
d/ Excludes nonfuel uses.
e/ GNP growth rate at 3.5 percent per year and (4.0 percent per year).

Source: Pacific Northwest Laboratories of Battelle Memorial Institute, A Review and Comparison of Selected United States Energy Forecasts, December 1967.

Identification of Source Documents
(referred to in appendix tables 1 through 6)

NF & ES — U.S. Congress. Senate. Committee on Interior and Insular Affairs. Report of the National Fuels and Energy Study Group on Assessment of Available Information on Energy in the United States. September 1962.

ERDNP — Energy Study Group. Energy R&D and National Progress Interdepartmental Energy Study. Prepared by Ali Bulent Cambel. Washington, D.C.: U.S. Government Printing Office, June 1964.

USP — U.S. Department of Interior. Office of Oil and Gas. United States Petroleum Through 1980. July 1968.

FGNP — United States Atomic Energy Commission. Division of Operations Analysis and Forecasting. Forecast of Growth of Nuclear Power. WASH-1084. 1967.

PEC — U.S. Department of the Interior. Patterns of Energy Consumption in the U.S. Prepared for Division of Economic Analysis of Bureau of Mines by William A. Vogely. 1962.

GUPIP — American Gas Association. Department of Statistics. Gas Utility and Pipeline Industry Projections. 1968-1972, 1975, 1980 and 1985.

FNGR — Denver Research Institute. Future Requirements Agency. Future Natural Gas Requirements of the United States. Vol. 2. Denver: University of Denver, June 1967. (Under the auspices of the Gas Industry Committee).

CGAEM — Texas Eastern Transmission Corporation. Competition and Growth in American Energy Markets, 1947-1985. 1968.

NPS	Federal Power Commission. National Power Survey. Washington, D.C.: U.S. Government Printing Office, 1964.
ER	National Academy of Sciences. Energy Resources - A Report to the Committee on Natural Resources. Publication 1000-D. Prepared by M.K. Hubbert for the National Research Council, 1962.
EUS	Sartorius & Company. Energy in the United States, 1960-1985. Prepared by Michael C. Cook. September 1967.
RAF	Resources for the Future, Inc. Resources in America's Future. Prepared by Landsberg, Fischman, and Fisher. Baltimore: John Hopkins Press, 1963.
TCUSEC	Strout, Alan M. "Technological Change and United States Energy Consumption, 1939-1954." Ph.D. dis., University of Chicago, 1968.
EMUS	U.S. Department of the Interior. Bureau of Mines. An Energy Model for the United States Featuring Energy Balances for the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000. IC 8384. July 1968.
OEUS	The Chase Manhatten Bank. Energy Division. Outlook for Energy in the United States. October 1968.
ESDNR	MacAvoy, Paul W. Economic Strategy for Developing Nuclear Reactors. Cambridge, Mass.: Massachusetts Institute of Technology Press, 1969.
FFF	United States Atomic Energy Commission. Fossil Fuels in the Future. Prepared for the Office of Operations Analysis and Forecasting by Milton F. Searl. 1960.
PCCP	Public Land Law Review Commission. Projections of the Consumption of Commodities Producible on the Public Lands of the United States 1980-2000. Prepared by Robert R.

Nathan Associates, Inc., Washington, D.C. May 1968.

CNP U.S. Atomic Energy Commission. Civilian Nuclear Power - A Report to the President. 1962 (and 1967 Supplement).

Appendix table 2. Forecasts of Annual Growth Rates in Total Energy Requirements

Source	To base year(s)	1970-75	1975-80	1980-85	1985-90	1990-2000
CGAEM.......	←		.037	→		
EUS.........	←	.042 →	← .044	→ ←	.047 →	
RAF.........	←	.027 →	←	.025	→	
EMUS........	←		.032			→
PCCP........				←	.031	→
FFF.........	←	.034		→ ←	.035	→
PEC.........	←	.032		→		
OEUS........	←	.038		→		
ER..........	←		.0204			→
USP.........	←		.031	→ (Petroleum only)		
	←		.029	→ (Natural gas only)		
NF & ES.....	←	.032	→			

Note: Growth rates generally indicate the compound annual rate of growth from the average value for one period to the average of another period.

Source: Pacific Northwest Laboratories of Battelle Memorial Institute, A Review and Comparison of Selected United States Energy Forecasts, December 1969.

considerable variation among them as would be expected from the differences in the quantitative projections themselves. Only one study (Energy in the United States by Michael C. Cooke of Sartorius and Company) assumed a compound growth rate of energy consumption in excess of 4 percent annually during any forecast period to 2000, and several were less than 3 percent. Most studies appear to have assumed an energy consumption growth rate below the assumed growth of GNP. This is consistent with the historical correlation of these two trends until approximately 1965. In more recent years there has been a change in this relationship, and the growth of energy consumption has exceeded the growth of GNP. This is the subject of a recent paper prepared by National Economic Research Associates (NERA), which found that the energy consumption/GNP ratio, which had shown a long-term decline since 1946, was reversed in 1966.1/

NERA concluded that the reversal of the energy consumption/GNP ratio from the long-term trend of less than unity to above unity in the period 1966-70 may have been due to fundamental changes in the energy consumption pattern. These included the higher proportion of consumption of electricity, a less efficient use of primary energy than some direct uses, increased nonenergy use of fuels, and a leveling off and even a reversal of the long-term decline in the average heat rate at central power stations.

However, the reversal of the relationship in the energy consumption/GNP ratio was also the subject of an informal memorandum prepared by Warren E. Morrison of the Bureau of Mines on March 22, 1971. Morrison did not attempt to analyze possible changes in energy consumption patterns, but did conclude from his analysis that "it is premature to assume that a basic shift in the GNP/energy proportionate relationship over time has occurred." His basic finding is that there has historically tended to be a lag in the response of changes in

1/ National Economic Research Associates, Energy Consumption and Gross National Product in the United States, March 1971.

the rate of growth of GNP. The average rate of growth of GNP during 1965-70 was 3.2 percent, compared with an average of 4.8 percent during 1960-65. Growth rates of gross energy inputs during these periods were 5.0 and 3.6 percent, respectively.

Appendix table 3 is the summary of the Battelle forecasts of the U.S. petroleum and natural gas liquid requirements, and their percentage of total projected energy requirements. Appendix tables 4 and 5 present these same data converted to millions of barrels and short tons annually, using an average conversion of 5.8 million B.t.u.'s per barrel.

The forecasts of petroleum and natural gas liquid requirements in 1980 range from 5.16 billion barrels, or 14.1 million barrels per day, to 6.9 billion barrels, or 19 million barrels per day.

In the four studies that had forecasts for the year 2000, the range of petroleum and natural gas liquid requirement estimates is from 9.1 to 12.2 billion barrels, or from 25 to 33.6 million barrels per day. However, the forecasts from the Robert R. Nathan Associates study (PCCP) for which the low estimate is shown, do not include the estimated requirements for natural gas liquids, for which separate estimates were made. When adjusted for this omission, the estimated requirements would be the equivalent of 17.3 million and 30.4 million barrels per day in 1980 and 2000, respectively.

This result for the year 2000 is much more nearly comparable to the projections in Resources in America's Future, of which the PCCP was largely an updating. The projections in both these studies then fall between the high estimate of the Atomic Energy Commission in Fossil Fuels in the Future and the low of the Bureau of Mines study entitled An Energy Model for the United States.

Appendix table 3. Forecasts of U.S. Petroleum and NGL Requirements with Percent of Total Energy

(In trillions of B.t.u.'s)

Source	1970	1975	1980	1985	2000
CGAEM............	28,127	33,764	40,174	47,625	--
Percent.........	43.6	42.4	41.1	39.8	
EUS a/............	24,275	27,069	29,943	32,762	--
Percent.........	39.9	36.1	32.1	27.7	
NF & ES..........	--	--	33,000	--	--
Percent.........			40.2		
RAF..............	25,140	--	32,910	--	61,670
Percent.........	41.8		41.6		45.6
PEC..............	--	--	36,042	--	--
Percent.........			41.9		
OEUS.............	--	--	39,927 b/	--	--
Percent.........			41.2		
USP..............	--	--	36,000	--	--
Percent.........			40.9		
FFF..............	--	--	38,000	--	71,000
Percent.........			44.1		41.8
PCCP b,c,d/.......	--	--	30,300	--	52,800
Percent.........			34.7		35.0
EMUS.............	27,275	31,875	35,578	--	57,600
Percent.........	42.4	42.2	40.8		34.2

a/ Specifically excludes nonenergy fuel use.
b/ Converting the forecasted barrels of oil to B.t.u.'s at 5,800,000 B.t.u.'s per barrel.
c/ Medium projection, includes agriculture, asphalt and road oil, liquid refinery gas, miscellaneous uses and exports.
d/ Figures shown for 1980 and 2000 are crude oil only. Correct figures, including natural gas liquids, would be 36.5 and 65.3 quadrillion B.t.u.'s, respectively.

Source: Pacific Northwest Laboratories of Battelle Memorial Institute, A Review and Comparison of Selected United States Energy Forecasts, December 1969.

Appendix table 4. Forecasts of U.S. Petroleum and NGL Requirements with Percent of Total Energy[a]

(In millions of barrels)

Source	1970	1975	1980	1985	2000
CGAEM.............	4,849.5	5,821.4	6,926.6	8,211.2	--
Percent..........	43.6	42.4	41.1	39.8	
EUS[b].............	4,185.3	4,667.1	5,162.6	5,648.6	--
Percent..........	39.9	36.1	32.1	27.7	
NF & ES...........	--	--	5,689.7	--	--
Percent..........			40.2		
RAF..............	4,334.5	--	5,674.1	--	10,632.8
Percent..........	41.8		41.6		45.6
PEC..............	--	--	6,214.1	--	--
Percent..........			41.9		
OEUS.............	--	--	6,884.0	--	--
Percent..........			41.2		
USP..............	--	--	6,206.9	--	--
Percent..........			40.9		
FFF..............	--	--	6,551.7	--	12,241.4
Percent..........			44.1		41.8
PCCP[c,d].........	--	--	5,244.1	--	9,103.4
Percent..........			34.7		35.0
EMUS.............	4,702.6	5,495.7	6,134.1	--	9,931.0
Percent..........	42.4	42.2	40.8		34.2

a/ Forecasted B.t.u.'s converted to barrels of oil at 5,800,000 B.t.u.'s per barrel.
b/ Specifically excludes nonenergy fuel use.
c/ Medium projection, includes agriculture, asphalt and road oil, liquid refinery gas, miscellaneous uses and exports.
d/ Figures shown for 1980 and 2000 are crude oil only. Correct figures, including natural gas liquids, would be 6,293.1 and 11,258.6 millions of barrels, respectively.

Source: Appendix table 3.

Appendix table 5. Forecasts of U.S. Petroleum and NGL Requirements with Percent of Total Energy[a]

(In millions of short tons)

Source	1970	1975	1980	1985	2000
CGAEM.............	746.1	895.6	1,065.6	1,263.3	--
Percent.........	43.6	42.4	41.1	39.8	
EUS[b]............	643.9	718.0	794.2	869.0	--
Percent.........	39.9	36.1	32.1	27.7	
NF & ES..........	--	--	875.3	--	--
Percent.........			40.2		
RAF..............	666.8	--	872.9	--	1,635.8
Percent.........	41.8		41.6		45.6
PEC..............	--	--	956.0	--	--
Percent.........			41.9		
OEUS.............	--	--	1,059.1	--	--
Percent.........			41.2		
USP..............	--	--	954.9	--	--
Percent.........			40.9		
FFF..............	--	--	1,008.0	--	1,883.3
Percent.........			44.1		41.8
PCCP[c,d].........	--	--	803.7	--	1,400.5
Percent.........			34.7		35.0
EMUS.............	735.5	845.5	943.7	--	1,527.8
Percent.........	42.4	42.2	40.8		34.2

a/ Forecasted barrels of oil are converted to short tons at 6.5 barrels per ton.
b/ Specifically excludes nonenergy fuel use.
c/ Medium projection, includes agriculture, asphalt and road oil, liquid refinery gas, miscellaneous uses and exports.
d/ Figures shown for 1980 and 2000 are crude oil only. Correct figures, including natural gas liquids, would be 968.2 and 1,732.1 millions of short tons, respectively.

Source: Pacific Northwest Laboratories of Battelle Memorial Institute, A Review and Comparison of Selected United States Energy Forecasts, December 1969.

Review of Demand Supply Projections Since 1968

Appendix table 6 is a summary of more recent projections of U.S. petroleum demand and supply. The most recent is the July 15, 1971, report to the Secretary of the Interior by the National Petroleum Council (NPC), entitled U.S. Energy Outlook: An Initial Appraisal 1971-1985. This report was prepared in response to a request from the Secretary of the Interior to the NPC, a quasi-official body established by the Federal Government and composed of representatives of Government and industry. Its projections of demand and sources of supply, as well as the projections by the petroleum companies and by the Petroleum Industry Research Foundation, an industry-financed institution, must be viewed in the light of the fundamental questions regarding U.S. petroleum import and pricing policy raised by the February 1970 report of the Cabinet Task Force on Oil Import Control entitled The Oil Import Question.

The Task Force projected, to 1980, U.S. demand for petroleum liquids and U.S. supply from indigenous and foreign sources under three basic hypotheses regarding average prices for U.S. domestic crude petroleum: (1) continuation of the present average price, (2) a reduction of this price by 80 cents, and (3) a reduction of the price by $1.30. Assumptions were also made with respect to the liberalization of U.S. petroleum import policy.1/

The Task Force estimate of petroleum demand in 1980 at present prices is 19.3 million barrels per day, an average annual increase over 1970 of 2.7 percent. At current prices the Task Force projected total imports of 5.8 million barrels per day (an increase of 2.4 million barrels per day over 1970 imports), increasing to

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1/ The Task Force used a current average price of $3.30 per barrel, which is understood to correspond with the average price for Louisiana crude, whereas the average U.S. crude price is understood to be $3.10 per barrel.

Appendix table 6. Comparative Recent Projections of U.S. Demand and Supply of Petroleum and Natural Gas Liquids

(In millions of barrels daily)

Source	Total demand[a]	Production: Lower 48: Crude oil	Production: Lower 48: Shale oil synthetics	Production: Alaska	Imports: Canada	Imports: South America	Imports: Eastern Hemisphere	Imports: Total	Imports: Percent of supply
National Petroleum Council									
1970	14.7	11.3	--	--	n.a.	n.a.	n.a.	3.4	23.1
1975	18.4	10.5	--	0.6	n.a.	n.a.	n.a.	7.3	39.7
1980	22.5	9.8	--	2.0	n.a.	n.a.	n.a.	10.7	47.6
1985	26.0	9.1	0.1	2.0	1.9	n.a.	n.a.	14.8	56.9
Cabinet Task Force									
1980:									
$3.30[b]	19.3	11.5	--	2.0	2.6	2.7	0.5	5.8	30.1
$2.50[b]	19.7	9.0	--	2.0	3.0	3.8	1.9	8.7	44.2
$2.00[b]	20.0	7.5	--	2.0	1.5	3.7	5.3	10.5	52.5
Petroleum Industry Research Found.									
$3.10:[b]									
1980	22.8	10.5	--	2.2	2.2	2.7	5.2	10.1	44.3
1985	27.6	10.5	--	3.0	3.0	2.9	8.2	14.1	51.1
$2.30:[b]									
1980	25.2	7.8	--	2.2	2.2	2.7	10.3	15.2	60.3
1985	30.3	6.3	--	2.2	3.0	2.9	15.9	21.8	71.9
$3.83:									
1980	22.8	12.8	--	2.5	2.5	2.7	2.3	7.5	32.9
1985	27.1	14.7	--	3.6	3.2	2.9	2.7	8.8	32.5
Humble Oil and Refining Company - I									
$3.30:[b]									
1980	22.7	10.6	--	2.0	1.6	2.0	6.5	10.1	44.5
1985	26.8	n.a.	n.a.	n.a.	n.a.	n.a.	10.0	n.a.	--
$2.50:[b]									
1980	23.5	7.8	--	2.0	1.5	2.0	10.2	13.7	58.3
1985	26.8	n.a.	n.a.	n.a.	n.a.	n.a.	16.1	n.a.	--
Humble Oil and Refining Company - II									
1980	24.5	8.8[c]	0.2	2.0	---- 3.7 ---		9.8	13.5	55.1
1985	28.1	7.7[c]	1.0	2.0	---- 4.4 ---		13.0	17.4	61.9
Chase Manhattan Bank									
1980	25.0	10.0	--	2.5	2.0	3.2	7.3	12.5	50.0
Department of Interior, Alaska Pipeline Impact Statement									
1980	22.3	12.5[c]	--	2.0	1.6	3.3	3.0	7.9	35.4
1985	27.1	12.3[c]	--	3.0	2.2	3.5	6.2	11.9	43.9

continued--

Appendix table 6. Comparative Recent Projections of U.S. Demand and Supply of Petroleum and Natural Gas Liquids continued--

(In millions of barrels daily)

Source	Total demand[a]	Production			Imports				
		Lower 48							
		Crude oil	Shale oil synthetics	Alaska	Canada	South America	Eastern Hemisphere	Total	Percent of supply
Gulf Oil Company (PIRF)									
$2.50:[b]									
1980	19.7	8.8			1.4	2.1	7.4	10.9	55.3
Shell Oil Company - I									
1980	21.0	11.0	--	2.0	n.a.	n.a.	n.a.	8.0	38.1
Shell Oil Company - II									
1980	25.0	10.6			2.0	n.a.	n.a.	14.4	57.6
1985	30.0	7.0	0.8	2.2	2.0	n.a.	n.a.	18.0	60.0
Litton Systems									
1980	18.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2003	30.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Mineral Facts and Problems									
2000	20.0-45.0	15.3-35.4	n.a.	n.a.	n.a.	n.a.	n.a.	3.9-8.5	19.5
Secretary of Interior									
1975	17.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1985	23.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2000	32.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Conventional Energy Model (revised)									
1980	18.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2000	26.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

a/ Net of adjustments for stock changes, exports, processing gain.
b/ Assumed U.S. crude price.
c/ Including refinery gains.

Source: National Petroleum Council, U.S. Energy Outlook, An Initial Appraisal 1970-1985, an Interim Report Prepared by the National Petroleum Council's Committee on U.S. Energy Outlook, vol. 1, Washington, D.C., July 1971. Cabinet Task Force, The Oil Import Question, A Report on the Relationship of Oil Imports to the National Security by the Cabinet Task Force on Oil Import Control, February 1970. Petroleum Industry Research Foundation, Oil Imports and the National Interest, March 1971, and the Supplement, March 1971. Humble Oil and Refining Company - I, Statement by M.A. Wright on Oil Imports Before House Ways and Means Committee, June 3, 1970. Humble Oil and Refining Company - II, M.A. Wright, "U.S. Energy Crisis and What Can Be Done About It," Ocean Industry, June 1971. Chase Manhattan Bank, Testimony of John D. Emerson, at the West Louisiana Federal Lease Sale Hearing, New Orleans, July 15, 1970. Alaska

Appendix table 6. Comparative Recent Projections of U.S. Demand and Supply of Petroleum and Natural Gas Liquids continued--

Pipeline Impact Statement, Environmental Impact Statement for the Trans-Alaska Pipeline, prepared by Department of the Interior, January 1971. Gulf Oil Company, Statement of E.D. Loughney before Edmondson Committee, April 1, 1970, extracted from PIRF Study on Oil Imports and the National Interest. Shell Oil Company - II, Visual and Oral Presentation to the U.S. Army Corps of Engineers in Washington on June 22, 1971. Litton Systems, Ocean-Borne Shipping, Demand and Technology Forecast. Minerals Facts and Problems, Department of Interior, 1970. Secretary of Interior, Before Committee on Interior and Insular Affairs, June 15, 1971. Department of the Interior, Bureau of Mines, Energy Model for the U.S., Information Circular 8384 (Rev. August 31, 1970), table 35A.

8.7 million barrels per day at the $2.50 price and to 10.5 million barrels per day at $2.00 per barrel. Production in the lower 48 states at 11.5 million barrels daily is approximately the same as in 1970, and under the reduced price assumptions declines to 9.0 and 7.5 million barrels per day.

The studies by the Petroleum Industry Research Foundation and by the Humble Oil and Refining Company and Gulf Oil Company were specific responses to the report of the Cabinet Task Force. Whereas they did not disagree seriously with the Task Force estimate of U.S. crude production at the $3.30 price, they did project somewhat lower levels of production at the hypothesized crude price reductions, and they also projected U.S. petroleum demand at about 10 percent above the Task Force projections. The 1971 demand projections by Humble Oil and Shell Oil are substantially higher for the years 1980 and 1985 than those made approximately a year earlier. They are also substantially higher than the estimates of the NPC.

The latter report, having been prepared by a number of committees, subcommittees and task groups composed of representatives of Government, and principally the petroleum and coal industries, may be regarded as a composite view of these interests on the future of petroleum demand and indigenous production probabilities under the assumptions used. The letter of transmittal to the Secretary of Interior stated that supply-demand relationships were projected "under certain assumed conditions which involve minimal changes from present policies, practices and economic climate. In particular, it has been assumed that current trends of government policy and regulation would continue without major change and that the present economic climate for the energy industries would be maintained throughout the 1971-1985 period."

Of the other studies for which data are included in appendix table 6, only Minerals Facts and Problems by the Bureau of Mines includes estimates of indigenous production and imports, and these are only for 2000. The demand projections are defined as "contingency

forecasts," and the accompanying analysis provides no judgment as to probability within the very broad range of the forecasts. The balance between indigenous production and imports assumes a continuation of the relationship to demand that existed in 1968.

The projections by the Secretary of Interior are described as "estimated probable demand" and were developed within the framework of estimates of total gross energy requirements and estimates of the shares of each of the major energy sources in the supply. His estimate of a U.S. demand in 1985 of 23.6 million barrels daily is the lowest of all of the studies for which data are included in the table.

The 1980 projection in the Conventional Energy Model (a revision of the EMUS in tables 3,4, and 5), another Department of Interior source, is also low. The projection for 2000 of 26.4 million barrels daily compares with the estimate by the Secretary of Interior of 32.8 million. The projections in the statement of the Secretary of Interior and in the Conventional Energy Model are understood to be prepared by essentially the same professional staff. However, the Secretary's statement was prepared more recently and incorporates probability judgments to a greater extent than the Energy Model.

The NPC estimated the requirement for petroleum imports from foreign sources including Canada, which were 3.4 million barrels daily in 1970, at 10.7 and 14.8 million barrels daily in 1980 and 1985, respectively. These estimates are approximately the median of the range of estimates for 1980 and 1985 among all of the studies for which data are summarized in appendix table 6: from 5.8 to 14.4 million barrels daily in 1980 and from 11.9 to 18.0 million barrels daily in 1985.

It is with these projections of requirements for imports, particularly from offshore sources, that we are most concerned in this study. Assuming receipts of approximately 2 million barrels per day each from Alaska and from Canada, for which there do not appear to be

very significant differences among the various sources, the import requirement from foreign offshore sources in the National Petroleum Council study would be 8.7 and 12.8 million barrels daily in 1980 and 1985, respectively, or the equivalent of from approximately 500 million short tons to over 700 million short tons annually. The level of imports in 1985 would be equal to the total U.S. demand for petroleum in 1970.

Even on the basis of the most conservative projections of U.S. petroleum demand and the most liberal projections of indigenous production by the various sources in appendix table 6, the prospective volumes of foreign offshore imports imply a need for ocean transportation and port facilities for which there is no precedent in the import of either dry bulk or liquid bulk commodities into the United States.

As was shown in appendix table 2, most of the total energy forecasts reviewed in the Battelle report assumed or implied growth rates through 1980 and 1985 of less than 4 percent, and Resources in America's Future had a growth rate of 2.7 percent to 1980 and 2.5 percent from 1980 to 2000.

Appendix table 7 shows total U.S. energy demand projections where they are available from the studies for which petroleum data were shown in appendix table 6. The range for 1980 is from 95.1 to 110.0 quadrillion B.t.u.'s, compared with a range in appendix table 1 of from 61.0 to 99.7 quadrillion B.t.u.'s. Thus the studies prepared during the last year or two all assumed higher levels of consumption of energy than do the earlier studies. The implicit annual compound growth rates from 1970 to 1980 given in appendix table 7 range from 3.4 percent to 4.8 percent.

The 1985 range of estimates is narrower than for 1980, from 124.9 to 133.4 quadrillion B.t.u.'s; all are higher than the earlier projections.

Appendix table 7. Comparative Recent Projections of Total U.S. Energy Demand

(In quadrillions of B.t.u.'s)

Source	1970	1975	1980	1985	2000
National Petroleum Council...	67.8	83.5	102.6	124.9	--
Petroleum Industry Research Foundation.................	68.8	86.2	105.3	128.5	--
Humble Oil and Refining Company - I................	68.8	85.0	105.0	130.0	--
Chase Manhattan Bank.........	68.8	--	110.0[a/]	--	--
Mineral Facts and Problems, Contingency Forecasts, 1970.	68.8	--	--	--	166.0-239.1
Secretary of Interior........	68.8	88.6	--	133.4	191.6
Conventional Energy Model....	68.8	--	95.1	--	168.6

a/ Converted from 52 million barrels daily at 5.8 million B.t.u.'s per barrel.

Source: See appendix table 6.

For 2000 we have only the Department of the Interior's sources. The Secretary's estimate is 191.6 quadrillion B.t.u.'s. The implied annual compound growth rate from 1970 is 3.5 percent.

The share of petroleum in the total energy market is a function of a wide range of technical, economic, and policy variables. In 1970 it was 43 percent. There is a negligible difference between the share of crude petroleum in the total energy market projected by the National Petroleum Council, the Petroleum Industry Research Foundation, and Humble Oil, the percentages for 1985 being 42.2, 44.0, and 43.0, respectively. Chase Manhattan Bank, on the other hand, estimates the petroleum share at 48 percent of the total.

The Secretary of Interior projects a decline to 35.6 percent in 1985 and 34.6 percent in 2000.

The relatively higher share in the Chase Manhattan estimates is attributed principally to a substantial shortfall in the projected supply of natural gas, and a shift to fuel oil by the year 1980 of the equivalent of 3.5 million barrels daily of natural gas demand. Similar assumptions are made in the other studies, but the amount of shift from natural gas to fuel oil is not stated.

Another influence tending to keep the share of petroleum at high levels is the impact of air pollution control regulations which have brought about a substantial shift of industrial and electrical utility fuel consumption from high-sulfur coal to low-sulfur fuel oils.

Appendix table 8 shows the compound growth rates for the intervals from 1970 for the various projections of petroleum demand appearing in appendix table 6. For 1970-80, the projections by industry sources cluster around the 4 and 5 percent level, and for 1980-85, they decline to the 3 and 4 percent level. For 1980-85 to 2000, the projections from Department of the Interior sources are down to the 2 percent range.

Appendix table 8. Comparative Projections for U.S. Demand of Petroleum and Natural Gas Liquids with Growth Rates

Source	Projections (millions of barrels daily)					Growth rate (percent)						
	1975	1980	1985	2000	2003	1970-75	1975-80	1980-85	1970-80	1975-85	1980-2000	1970-2000
National Petroleum Council	18.4	22.5	26.0	--	--	4.6	4.1	2.9	4.3	--	--	--
Cabinet Task Force:												
$3.30	--	19.3	--	--	--	--	--	--	2.8	--	--	--
2.50	--	19.7	--	--	--	--	--	--	3.0	--	--	--
2.00	--	20.0	--	--	--	--	--	--	3.1	--	--	--
Petroleum Industry Research Foundation:												
$3.10	--	22.8	27.6	--	--	--	--	3.9	4.5	--	--	--
2.30	--	25.2	30.3	--	--	--	--	3.8	5.5	--	--	--
3.83	--	22.8	27.1	--	--	--	--	3.5	4.5	--	--	--
Humble Oil and Refining Company - I:												
$3.30	--	22.7	26.8	--	--	--	--	3.4	4.4	--	--	--
2.50	--	23.5	26.8	--	--	--	--	2.7	4.8	--	--	--
Humble Oil and Refining Company - II	--	24.5	28.1	--	--	--	--	2.8	5.2	--	--	--
Chase Manhattan Bank	--	25.0	--	--	--	--	--	--	5.5	--	--	--
Department of Interior, Alaska Pipeline Impact Statement	--	22.3	27.1	--	--	--	--	4.0	4.3	--	--	--
Gulf Oil Company:												
$2.50	--	19.7	--	--	--	--	--	--	3.0	--	--	--
Shell Oil Company - I.	--	21.0	--	--	--	--	--	--	3.6	--	--	--
Shell Oil Company - II.	--	25.0	30.0	--	--	--	--	3.7	5.5	--	--	--
Litton Systems	--	18.3	--	--	30.2	--	--	--	2.2	--	2.2 a/	2.2 b/
Mineral Facts and Problems	--	--	--	20.0-45.0	--	--	--	--	--	--	--	1.0-3.8
Secretary of Interior	17.9	--	23.6	32.8	--	4.0	--	--	--	2.8	2.2 c/	2.7
Conventional Energy Model	--	18.9	--	26.4	--	--	--	--	2.6	--	1.7	2.0

Note: Base figure of 14.7 for 1970 used in all growth rate calculations.
a/ Projection, 1980-2003.
b/ Projection, 1970-2003.
c/ Projection, 1985-2000.

These growth rates for 1970-80 compare with an actual growth rate in domestic demand for petroleum products of 4.1 percent for 1960-70. However, the growth rate for 1960-68 was 4.0 percent, and for 1968-70 was 4.7 percent, with the major part of the increase in the latter period occurring in residual fuel oil and motor gasoline appendix (table 9).

Appendix table 9. U.S. Domestic Demands for Petroleum Products, 1960, 1968 and 1970

(In millions of barrels)

Petroleum products	Demand			Growth rates		
	1960	1968	1970	1960-68	1968-70	1960-70
Motor gasoline.....	1,453	1,925	2,111	3.6	4.7	3.8
Aviation gasoline..	59	31	20	11.2	-1.1	8.7
Jet fuel..........	103	349	352			
Liquefied gases....	227	331	371	4.8	5.9	5.0
Kerosine..........	132	103	96	-3.1	-3.6	-3.1
Distillate fuel oil..............	658	875	927	3.1	2.9	3.1
Residual fuel oil..	559	668	804	2.2	9.7	3.7
Asphalt...........	105	141	153	3.7	4.9	3.9
Still gas.........	129	150	164	1.9	4.6	2.4
Petrochemical feedstocks........	n.a.	93	101	n.a.	4.2	n.a.
Other.............	n.a.	235	272	n.a.	7.6	n.a.
Total............	3,586	4,901	5,371	4.0	4.7	4.1

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1960 and 1968; and Mineral Industry Surveys, "Monthly Petroleum Statement," December 1970, prepared by the Division of Fossil Fuels, March 23, 1970.

ANNEX A-3. U.S. IRON ORE IMPORTS

CONTENTS

INTRODUCTION

The Changing Technology of Steel

Projection of historical trends 20 and 30 years into the future is always a hazardous exercise. It is particularly so in the steel industry which now, more than in any other period of this century, faces rapidly changing economic and technical forces. Every phase of current iron and steel technology, from the mining, preparation and transportation of iron ore to the smelting of iron ore and its transformation into raw and finished steel, is susceptible to change.

Change does not come to a great industrial complex all at once. In 1980 the U.S. steel industry will be different than it is now, but it will not be greatly different. We can with fair precision presently delineate some of these differences. For example, few observers of the steel industry will disagree with a prediction that open hearth steel production in the next 10 years will probably fall between 10 to 25 percent of total output of raw steel in the United States.1/ But as we project to the more distant future such as 1990 and 2000, the uncertainties grow. What will be the proportion of oxygen furnaces and electric furnaces? Will the composition of the metallic charge of these furnaces in those decades approximate the current composition? Will the blast furnace continue to be the dominant technology of producing iron from iron ore? Will

1/ See, for example, R. Teitig, Jr., "Predicting Changes in Steelmaking Processes," Iron and Steel Engineer, June 1970, p. 79.

U.S. imports of iron ore grow? How much iron and steel will the United States produce in 1990 and 2000? Many other questions relevant to forecasting can be raised. The ferment of change now visible makes it almost certain that the steel industry of 2000 will be much different than it is today. To forecast the tonnage of iron ore imports for the next three decades, it is necessary to evaluate the probable trend of the basic economic and technological forces and their interaction. Without such an analysis, forecasts of iron ore imports become arithmetical exercises in projecting existing trends. Judgments are necessary as to whether existing trends will continue at the same rate or at different rates, or whether they will reverse direction.

Contents

This annex contains four chapters and appendix material.

Chapter I is a summary that contains the following:

1. Tables of the forecasts of iron ore requirements, production and imports in terms of standard ore and actual ore, showing also the originating country and the U.S. port areas at which this ore will arrive.

2. A brief statement explaining these forecasts, highlighting some of their significant implications.

3. A table summarizing the values of the significant intermediary variables on which the iron ore forecasts depend.

4. A flow chart which diagrams the model upon which the analysis is based.

Chapter II contains the analysis of the expected changes in the technology of the iron and steel industry, the iron ore industry, the sources of U.S. imports of iron ore, and the economic relationship of scrap and primary iron.

Chapter III describes the basis of the forecasts of finished steel consumption and production, and of iron foundry production; the choice of the relevant technological variables; the computation of the metallic charge and its components (primary iron and scrap); the factors influencing domestic iron ore production and its comparison with imported iron ore from the major foreign supply sources; and the determination of total U.S. iron ore requirements.

Chapter IV contains an analysis of U.S. iron ore requirements and production by region, the calculation of U.S. imports by region, and their distribution by foreign source and U.S. ports of entry.

The appendix contains data used in the analysis but not presented in other sections of the report.

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I. SUMMARY

Iron Ore Defined

Tables 1 through 8 are the forecasts pertaining to iron ore for 1980, 1990, and 2000. Table 1 shows the national requirements, production and imports of direct shipping ore, agglomerates, concentrates, and prereduced iron ore (PRO), sometimes referred to as metallized ore. These primary iron-bearing materials are called "iron ore." The figures in table 1 are computed in terms of standard iron ore of 63 percent Fe content, a procedure adopted from the United Nations report, The World Market for Iron Ore.1/ Tables 2 to 5 distribute the import figures into countries of origin and U.S. receiving port areas, in terms of standard ore and actual tonnage expected to be imported. The difference between actual tonnage of iron ore and the tonnage of standard ore is due to the difference of iron content of the ores.

There is no doubt that iron ore will continue to be beneficiated in ever-greater amounts in future years with increasing iron content. For 1980 this will make only a small difference in actual tonnage; this difference will be about 3 million long tons less than standard ore. For 1990 and 2000 the differences become larger, both because U.S. imports will be larger and the iron content will be substantially higher. In 1990 the difference in actual ore and standard ore will be

1/ United Nations, The World Market for Iron Ore (ST/ECE/Steel/24), 1968.

Table 1. Estimated Iron Ore Requirements, Production and Imports, 1980, 1990, 2000

(In millions of long tons of standard ore)

Item	1980	1990	2000
Requirements....................	143.5	174.8	211.2
Production[a/]....................	88.8	106.3	125.6
Imports:			
Standard ore..................	54.7	68.5	85.6
Actual ore....................	51.4	60.6	72.3
Average Fe content of actual ore (percent)................	67.0	71.2	74.6

a/ Production excludes iron ore for exports which originate in the Mountain and Pacific Coast States, which are ore-surplus areas.

Table 2. Estimated Tonnage of Iron Ore Imports by Country of Origin, 1980, 1990, 2000

(In millions of long tons of standard ore)

Country	1980	1990	2000
Canada......................	28.6	35.0	43.2
Venezuela...................	16.4	20.4	25.1
Brazil......................	2.7	3.7	5.0
Peru-Chile..................	2.7	3.4	4.2
West Africa.................	3.8	5.1	6.3
Other.......................	.5	.9	1.8
Total......................	54.7	68.5	85.6

Table 3. Estimated Actual Tonnage of Iron Ore Imports by Country of Origin, 1980, 1990, 2000

(In millions of long tons)

Country	1980	1990	2000
Canada	27.3	31.5	36.3
Venezuela	14.8	17.1	20.7
Brazil	2.5	3.4	4.4
Peru-Chile	2.6	3.1	3.8
West Africa	3.7	4.7	5.7
Other	.5	.8	1.4
Total	51.4	60.6	72.3
Average Fe content (percent)	67.0	71.2	74.6

Table 4. Tonnage of Iron Ore Imports by U.S. Entry Port Areas and by Country of Export, 1980, 1990, 2000

(In millions of long tons of standard ore)

Exporting country	Zone 1 Northeast coast			Zone 2 Gulf coast			Zone 3 Great Lakes		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
Canada.............	5.0	5.3	6.5	1.7	1.8	2.3	21.9	27.9	34.4
Venezuela..........	11.4	14.2	17.4	5.0	6.2	7.7	--	--	--
Brazil.............	1.6	2.2	3.0	1.1	1.5	2.0	--	--	--
Peru-Chile.........	1.7	2.2	2.7	1.0	1.2	1.5	--	--	--
West Africa........	2.6	3.6	4.4	1.2	1.5	1.9	--	--	--
Other..............	.3	.5	.9	.2	.4	.9	--	--	--
Total..............	22.6	28.0	34.9	10.2	12.6	16.3	21.9	27.9	34.4

Table 5. Tonnage of Iron Ore Imports by U.S. Entry Port Area and by Country of Origin, 1980, 1990, 2000

(In millions of long tons of actual ore)

Country	Zone 1 Northeast coast			Zone 2 Gulf coast			Zone 3 Great Lakes		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
Canada...........	4.8	4.8	5.4	1.6	1.6	1.8	20.9	25.1	28.9
Venezuela.........	10.3	11.9	14.6	4.5	5.2	6.1	--	--	--
Brazil............	1.5	2.0	2.6	1.0	1.4	1.8	--	--	--
Peru-Chile........	1.6	2.0	2.4	1.0	1.1	1.4	--	--	--
West Africa.......	2.5	3.3	4.0	1.2	1.4	1.7	--	--	--
Other.............	.3	.5	.7	.2	.4	.7	--	--	--
Total..........	21.0	24.5	29.7	9.5	11.1	13.5	20.9	25.1	28.9
Total standard ore..............	22.6	28.0	34.9	10.2	12.6	16.3	21.9	27.9	34.4
Average Fe content (percent)...	67.8	72.0	74.0	67.6	71.5	76.0	66.0	70.0	75.0

Table 6. Projected Percent of U.S. Imports of Standard Iron Ore, by Country of Origin, 1980, 1990, 2000

Country	Percent of total imports		
	1980	1990	2000
Canada....................	52.3	51.1	50.5
Venezuela.................	30.0	29.8	29.3
Peru-Chile................	4.9	5.0	4.9
Brazil....................	4.9	5.4	5.8
West Africa...............	6.9	7.4	7.4
Others....................	.9	1.3	2.1
Total[a/]..................	100.0	100.0	100.0

a/ 1980 will not add to 100 percent due to rounding.

Table 7. Estimated Average Fe Content of Ores, Agglomerates and Super Ore by Country of Origin, 1980, 1990, 2000

(In percent Fe)

Country	1980	1990	2000
Canada	66	70	75
Venezuela	70	75	80
Peru-Chile	65	68	70
Brazil	66	70	72
West Africa	65	68	70
Others[a]	70	75	80

a/ Primarily Australian prereduced ores and agglomerates.

Table 8. Basis of Forecast of Iron Ore Imports
(In millions of net tons)

Steel consumption	1970	1980	1990	2000
Apparent consumption of finished steel...........................	96.7	124.9	156.1	194.9
Net imports (percent)...........	6.7	5.0	5.0	5.0
Finished steel production........	90.3	118.7	148.3	185.2
Steel continuously cast (percent).......................	15.0 a/	30.0	75.0	85.0
Raw liquid steel b/...............	131.3	164.4	183.1	233.1
Ingot steel equivalent of finished steel production b/.....	133.9	169.6	211.9	264.6
Primary iron consumption for raw steel production............	87.7 c/	97.9	119.5	144.6
Iron foundry production..........	14.8	16.9	19.0	21.4
Primary iron consumption -- foundries.....................	2.8 c/	2.5	2.9	3.2
Percentage of steel produced by:				
Basic oxygen furnace...........	48 c/	60	65	60
Electric furnace................	15 c/	25	30	38
Open hearth furnace............	37 c/	15	5	2

a/ Estimated.
b/ The figure of 131.3 million net tons is the American Iron and Steel Institute figure for ingot production. It is the sum of raw steel cast into ingots, and continuously cast. The forecasts (1980-2000) are the total raw liquid steel required, based upon the proportions of steel continuously cast and cast into ingots forecast for those years. "Ingot steel equivalent" for 1970 and 1980-2000 is the amount of ingot production required to produce the finished steel if all liquid raw steel was cast into ingots.
c/ Preliminary data.

about 8 million tons, and in 2000 the actual ore tonnage will be approximately 13 million tons less than imports calculated on a standard ore basis.

The figures shown in tables 1-8 refer to iron ore requirements of primary iron for finished steel, and iron foundry production. They do not include iron ore used for ferroalloys, pigments, and other miscellaneous uses. These uses, including manganese and other iron-bearing ores, are less than 2 percent of total iron ore requirements, which are shown in table 1.

Rates of Increase, 1980, 1990 and 2000

The rates of increase implied by the forecasts are shown in table 9.

Table 9. Percentage Change from Previous Decade in Requirements, Production and Imports of Iron Ore, 1980-2000a/

Year	Requirements	Production	Imports	
			Standard ore	Actual ore
1980..	11.0	13.0	33.7	27.5
1990..	21.8	19.7	25.2	17.9
2000..	20.8	18.2	25.2	19.3

a/ The percentage change from 1970 to 1980 is based upon the following 1970 figures: Requirements of 129.3 million long tons are computed on the basis of pig iron production of 90.5 million net tons. Production is based on production of iron ore of 83.2 million long tons (net of exports) of 59.5 percent Fe content. This is equivalent to 78.6 million tons of 63 percent Fe iron ore. Imports are based on preliminary figures for 1970 of 40.3 million long tons of approximately 64 percent Fe content, equivalent to 40.9 million tons of standard ore.

Several features of table 9 are worth noting. First, United States iron ore requirements after 1980 are expected to increase at a more rapid rate than during the decade 1970-80. The basic reason for this is our forecast that electric furnace production of steel will account for one-fourth of U.S. steel production in 1980 -- a more rapid increase than in the basic oxygen furnace (B.O.F.). Electric steel production increases from 15 percent of total steel output in 1970 to 25 percent of total output, an increase in relative share of 40 percent; the basic oxygen furnace increases from 48 percent of total output in 1970 to 60 percent on our forecast, an increase in relative share of 25 percent. Not all electric furnace steel production in 1980 will be based on virtually complete scrap inputs as is the current practice. Some will be use mixed inputs of scrap and prereduced ore (metallized ore) whose Fe content will average between 90 and 95 percent.

We expect that by 1980 the virtually all-scrap-charged electrics will account for 18 percent of total steel output, while the electric furnaces using prereduced ore (PRO) in a ratio of 45 percent scrap and 55 percent PRO will account for 7 percent of total output. In addition to this we expect that the cupola and air furnaces, the producers of iron for foundry products, will, in continuation of a long-term trend, use approximately 12 percent less pig iron per unit of foundry product in 1980 compared to 1970, or about .15 tons of pig iron per ton of foundry product. This ratio is expected to prevail from 1980 to 2000.

In the decades after 1980, iron ore requirements increase at about twice the rate as from 1970 to 1980. The reason is that in these later decades the share of scrap-based electrics declines while that of PRO electrics increases. In 1990 the scrap-based electric share declines to 15 percent of total steel, from 18 percent in 1980. The basic oxygen furnaces increase their share of total steel from 60 percent to 65 percent, and the PRO electrics increase from 7 percent to 15 percent. From 1990 to 2000, the scrap-based electrics decline to 13 percent of total steel output, while the PRO electrics increase from 15 percent to 25 percent of total steel output. From 1990 to 2000 all furnaces lose to the PRO electrics: scrap-based electrics lose 2 percent

of total share of steel output; open hearths lose 3 percent, and the basic oxygen furnaces lose 5 percent. The net effect is that the percentage change in iron ore requirements is slightly less in the decade 1990-2000 than in the decade 1980-90, as table 9 shows.

A second feature worth noting is that the percentage increase of the actual tonnage of iron ore is much less than that tonnage figured in terms of standard ore. The absolute differences amount to 3.3 million long tons, 7.9 million long tons and 13.3 million long tons in 1980, 1990, and 2000, respectively. As table 3 shows, the average iron content of all imported ore increases from 67.0 percent in 1980 to 74.6 percent in 2000. In 1970 this average iron content was approximately 63 to 64 percent. Table 6 gives our estimate of the proportion of imports from 1980 through 2000 for each originating country. The basis for these estimates is given in chapter II.

The U.S. Bureau of Mines believes that by 2000 all the ores produced in the United States will be agglomerates and that about half of the ore will be prereduced, so that the average Fe content of U.S. agglomerates in that year will be about 80 percent.1/ It should be observed that our estimate for foreign ores in 2000 is about 75 percent Fe content. The difference in the Fe content is due to the higher proportion of metallized ores which we expect in the United States.

A final point shown in table 9 is that even though our forecast shows an increasing rate of increase from decade to decade in U.S. production of ores and agglomerates, this rate is not sufficient to make the United States self-sufficient in iron ore or to reduce the proportion of imported ore in U.S. requirements. The reason for this is not the lack of iron ore reserves in the U.S. which can be beneficiated without technical problems, for the United States has enormous reserves

1/ U.S. Department of Interior, Preprint from the Bureau of Mines 1970 Minerals Yearbook, "Iron Ore," 1970, p. 70.

of such ores. The reason lies in the economics of domestic and foreign ore; in the fact that U.S. steel companies have invested extensively in foreign ore deposits, mining and beneficiating equipment; and in the higher cost of transport from major U.S. sources of iron ore, primarily Lake Superior ore to steel plants located on the eastern seaboard and the gulf coast. These steel plants are expected to grow more rapidly than either the Great Lakes steel facilities or the inland facilities in the Pittsburgh region. Thus, even though we forecast an absolute increase in domestic production of 10.2 million tons from 1970 to 1980, and 17.5 and 19.3 million tons respectively for the next two decades -- or 47 million tons of standard ore from 1970-2000 -- the actual proportion of iron content of imports to domestic requirements and production increases as shown in table 10.

Table 10. Proportion of Imports to Total Standard Ore Requirement and to Production, 1970-2000[a]

Year	Imports as percent of	
	Requirements	Production
1970.............	31.6	49.2
1980.............	38.1	61.6
1990.............	39.2	64.4
2000.............	40.5	68.2

a/ See footnote a, table 9, for basis of 1970 figures.

The 1980 value of imports as a proportion of total requirements of 38.1 percent is close to the U.N. forecast for 1980 (the most distant year it forecasts) of U.S. imports of 35.8 percent of requirements.

Assumptions of the Forecasts

The term "forecasts" has been used because the results shown are in our judgment the most likely point

figures for the years shown. They are not simply projections of historical time series, though many such projections are indeed involved. Underlying the forecasts is a selection from a range of possible technological and economic conditions bearing on the iron ore requirements, production, and imports of the United States in the next three decades. Table 8 contains the values of the intermediary variables on which the forecasts of total iron ore requirements are based. Our choice of economic and technological assumptions is explained in subsequent chapters of this report. Here we simply state the more important assumptions.

Relationship Between the Level and Composition of Economic Activity and the Consumption of Finished Iron and Steel

A close relationship exists between GNP, the measure of the level of economic activity, and iron and steel consumption. This relationship can easily be demonstrated by correlation analysis. Clearly more than the size of GNP (which we measure in 1958 dollars) is involved as a determinant of iron and steel consumption. Among the other factors are the composition of GNP, the competition of other materials which can be substituted for iron and steel, and the efficiency of industries which use iron and steel to produce goods and services made of or requiring iron and steel. (By "efficiency" we mean the materials-using efficiency.) Since our forecasts of iron and steel consumption are made in tons, the quality of steel itself will influence the tonnage (i.e., alloy steels can in some uses be substituted for nonalloy steels with consequent reduction in tonnage). Of all these factors there is no doubt that the size and composition of the GNP itself are the most important factors. A greater proportion of GNP is now accounted for by goods and services which use little steel. As a measure of all these influences we have used the ratio of apparent consumption of finished steel (ACFS) per billion dollars (1958) of GNP. This ratio has been declining in the past 20 years, and we expect it to decline further. In forecasting apparent consumption of finished steel for 1980, 1990, and 2000, a wide variety of methods are possible. We have chosen to forecast steel consumption directly at a growth rate of 2.25 percent per year,

in line with its historical trend. We have checked the reasonableness of these forecasts with the implied values of the ACFS/GNP ratio on the assumption of a 4 percent GNP growth and with various correlation models involving GNP. Chapter III deals more fully with this aspect of the problem.

Imports of Steel

Iron ore requirements depend upon iron and steel production rather than upon consumption. U.S. imports of steel have grown enormously in recent years, while U.S. exports of steel have been considerably less. On balance, the U.S. economy has been a net importer of steel, which means that U.S. production of steel is less than consumption. Recent governmental measures, i.e., the 10 percent surcharge on imports and the suspension of gold convertibility and devaluation of the dollar, are indications of official recognition of the seriousness of the overall import problem and the excess valuation of the U.S. dollar with respect to the major currencies of the world. In part because of these measures we assume that net steel imports will approximate 5 percent of apparent steel consumption, about one-half of the past several years.

Our basic reason, however, for this assumption is our expectation that U.S. steel efficiency relative to other countries will increase because the technological lag of U.S. steel producers, particularly in basic oxygen furnaces and large blast furnaces, is rapidly decreasing with respect to Japan and West Germany. In continuous casting, iron ore beneficiation, large electric furnaces, high-speed automated rolling mills, the use of direct reduction of iron ore, and the use of computers in the various elements of iron and steel making, the United States is not behind either the Japanese or West German producers. Further, the wage rates of these countries, though lower than U.S. rates, are increasing more rapidly. All these factors, together with the fact that in energy (electric power, coking coal and hydrocarbons) the United States has generally lower costs, lead us to believe that independently of external government measures, the United States will gradually become more competitive in steel.

We therefore expect that net imports as a percent of total steel consumption in the United States will decline to 5 percent.

Technological Assumptions

The basic technological assumptions with respect to iron and steel technology are shown in table 8. We expect the basic oxygen furnace to reach a peak of 65 percent of total raw steel output in 1990 and to decline to 60 percent in 2000. The electric furnace will increase sharply, but after 1980 we expect that more electric furnace capacity will operate on a PRO-scrap charge than on an all-scrap charge. In effect this means that a smaller proportion of primary iron will be made in blast furnaces than now. However, this fact by itself will not reduce iron ore requirements, though it will sharply reduce coking coal requirements.

An assumption which we have made is that the basic oxygen furnace will continue to operate on a 70:30 primary iron to scrap ratio. Basic oxygen furnaces, as demonstrated by Armco among others, can operate successfully on an all-scrap charge when the scrap is preheated prior to charge. Here the basic costs of fuel used to preheat scrap (electric power, fuel oil, coal, natural gas) compared to the costs of fuel used in blast furnaces (coke, fuel oil, natural gas) become critical factors. At current and prospective costs, the assumption we have made seems reasonable. However, in the decades after 1990 we expect this to change; we also expect that, because of the continuing high use of primary iron, scrap availability in the United States compared to the cost of primary iron may shift the balance so that higher scrap charges in the basic oxygen furnaces are likely.

The most important technological assumption pertains to the rate of introduction of continuous casting facilities. The higher the proportion of raw steel that is continuously cast, the less raw steel is required per unit of finished steel output compared to ingot casting. Because of this the total metallic input per ton of finished steel output is significantly reduced, and hence the requirements of primary iron and iron ore are reduced. Table 8 shows the difference in raw steel

and ingot equivalent as the proportion of continuously cast steel increases. We believe the rates we have chosen (i.e., 30, 75, and 85 percent for 1980, 1990 and 2000, respectively) to be realistic.

Geographic Assumptions

The U.S. steel industry is massive and is geographically widespread. Although its locations shift slowly, they nevertheless do shift. The major location along the Great Lakes will not change very much over the next three decades, both because of the great industrial complex which borders the lakes and because of the Lake Superior ores. On the other hand, the Pittsburgh region encompassing Pittsburgh, Youngstown, Weirton and Wheeling is likely to decline relative to other sections of the United States.

We expect coastal regions, particularly the North Atlantic and gulf coast regiors, to increase relatively to other steel-producing regions. The Pacific coast steel plants in California, Oregon and Washington will also increase more than proportionately to total steel output. Further, we expect that even the Pittsburgh region will probably increase in its use of imported ore.

We also believe that "mini plants," based upon electric furnaces operating in tandem with continuously cast billet facilities, will increase their proportion of total steel output. Some of these plants will operate on PRO-scrap charges and will thus find it advantageous to locate in coastal areas or regions not far removed from a supply of foreign-based metallized ores. For all these reasons we expect the major increase in imported ore to funnel through North Atlantic and gulf coast ports.

Iron Ore Exporting Countries

Our forecasts of the country of origin of imported ore are based upon two considerations:

1. Ownership by U.S. steel firms of iron ore reserves, pelletizing and other iron beneficiation facilities in foreign countries.

2. The economics of bringing iron ore to the United States. This includes the cost of production and transportation, and the quality of the ore, all of which influence the cost in the blast furnace. This latter factor depends on the complete chemical and physical makeup of the ore.

For some countries, notably Venezuela, all factors are favorable; there are captive U.S. mines, and Venezuelan ore is high quality, cheaply produced and favorably situated. Much Australian iron ore reserves are also partly owned by U.S. steel and iron ore interests, but the relatively high transportation cost of such ore places it at a disadvantage as a U.S. iron ore source.

Errors in Assumptions

Clearly our forecasts are likely to be in error. The important question is how large the errors will prove to be. With respect to 1980, we think the errors in table 1 are not in excess of plus/minus 10 percent. The error in forecasts of originating countries is likely to be greater. Peru, Chile, Brazil and West Africa are question marks, as is Australia. Nevertheless, though the estimates for these countries can be substantially in error (and the smaller the quantity, the higher the error), the forecast of port areas will not be affected by errors in originating countries.

For the decades after 1980 the possible errors are larger. It is possible that U.S. production of iron ore may be larger than we have estimated. This could come about because of political instability in ore-exporting countries, as in all the South American and West African countries; it could also result from more plentiful supplies of natural gas in the Lake Superior region, or cheaper sources of electric power from nuclear plants in that region. These factors could shift the other way -- if, for example, cheap sources of natural

gas, oil, and coal were to be found in the exporting countries, making these countries cheaper in prereduced iron ore production than the United States. Such factors cannot now be assessed. Similar uncertainties exist in the economic and technological factors. For this reason estimates for more remote periods, such as 1990 and 2000, should have much less weight in deepwater port planning than the 1980 forecast.

Methodology

The model used to obtain the estimates of iron ore imports by country of origin and by U.S. port of entry is an indirect method; that is, iron ore imports are not estimated by directly fitting a trend to iron ore imports. Rather they are estimated as the difference between U.S. iron ore requirements and iron ore production. This is done in three stages as shown in figure 1 which follows.

Stage I yields the requirements for total metallic inputs, consisting of primary iron, which generates the iron ore requirements, and scrap. Stage I has the following elements:

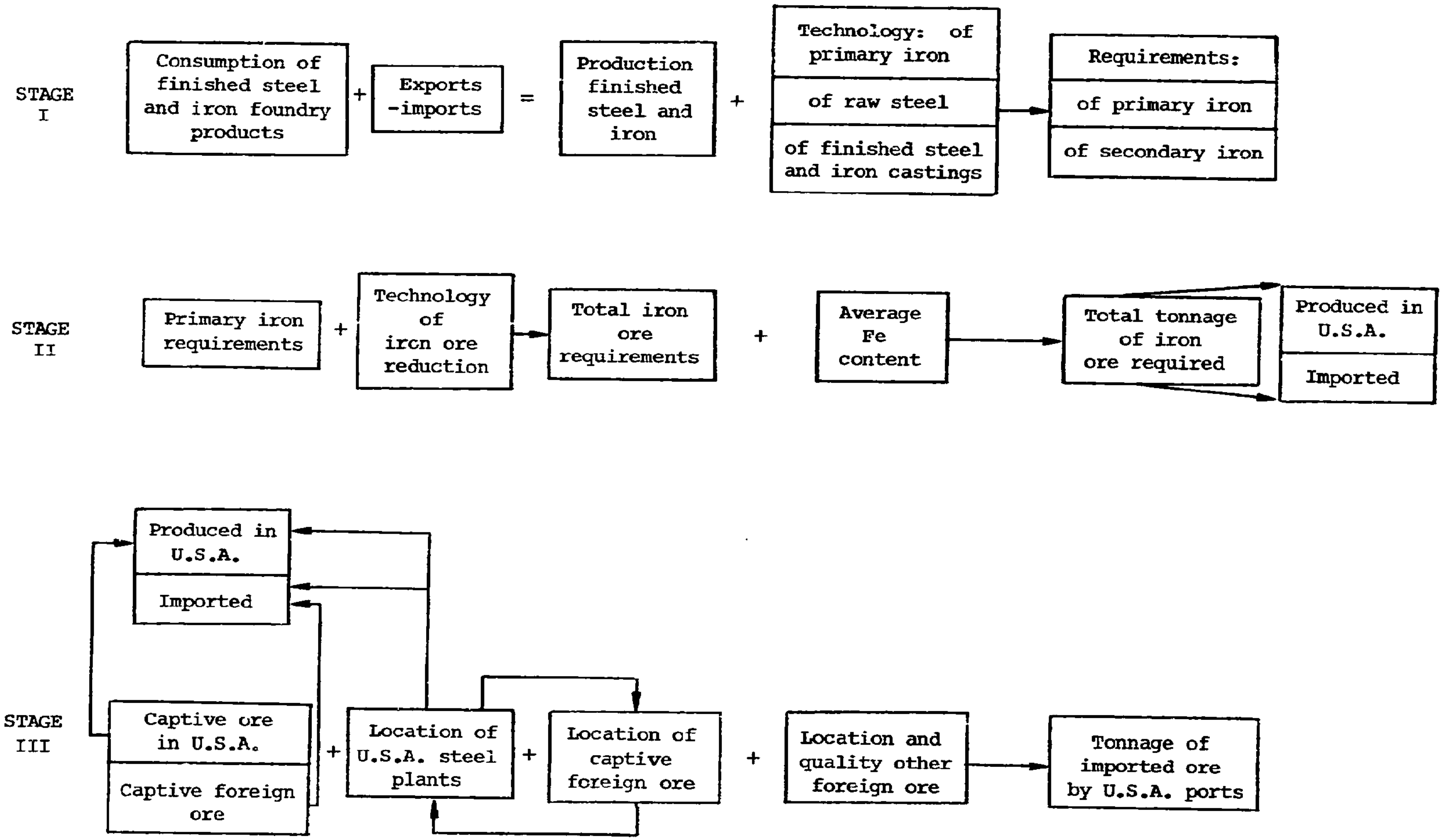
1. The consumption of finished steel is forecast. Numerous methods were tried, and the final estimate, as has been noted, was based upon a steel growth rate of 2.25 percent per year. The methods and data are described in detail in chapter III.

2. The net imports of finished steel were estimated at 5 percent of apparent consumption. The essential grounds for this have already been given. More detailed argument is contained in chapter III.

3. Finished steel production is derived by subtracting item 2 from item 1.

4. The technology of steel production is forecast in terms of the share of production and primary iron input for each furnace type. This is summarized in table 8. Similarly the technology of finished steel is forecast in terms of ingot casting and primary rolling mills yielding rolled slabs, blooms, and billets,

FIGURE 1. MODEL OF IRON ORE FORECASTS



and continuous casting yielding these semifinished steels in cast form. This is also shown in table 8. The technology of primary iron is also forecast in terms of the quantity of primary iron which will be made by direct reduction furnaces producing prereduced ore in metallized form for use in electric furnaces. The details of these technological forecasts and supporting economic considerations are given in chapters II and III.

5. On the basis of the forecasts in items 3 and 4, the requirements of primary iron are derived for 1980, 1990, and 2000.

Stage II of the model translates these primary iron requirements into standard ore of 63 percent Fe, and into actual ore as the iron content increases over the next decades. These iron requirements are divided into two components: U.S. domestic production and imports. Details are given in chapter II.

Stage III of the model breaks the imports derived in stage II into country of origin and port of entry. This is done on the basis of the following components:

1. The captive ore owned by U.S. steel companies in the United States and abroad.

2. A forecast of the percentage of total steel output to be made in the various producing regions of the United States.

3. The delivered cost of iron ore from the various U.S. iron ore sources abroad to the nearest U.S. port of entry. The details of stage III are given in chapter IV.

II. THE CHANGING TECHNOLOGY OF IRON AND STEEL

Iron Ore, Pig Iron, and Scrap

Use of Iron Ore

Iron ore, a mixture of iron oxides with other minerals, occurs widely in the earth's crust, the iron content of which has been estimated to be 5 percent. The iron content of iron ores varies considerably. Direct shipping ores (that is, ores used in U.S. blast furnaces without beneficiation) are usually over 50 percent Fe; ores below 50 percent Fe are beneficiated. In addition to increasing iron content and removing waste material (gangue), beneficiation also changes the physical character of the natural ore, making it more easily reduced in the blast furnace and thereby increasing output and lowering coke consumption.

The major use of iron ore is for the production of steel, an iron-carbon alloy (0.1 to 2.5 percent carbon). The tonnage steels are carbon steels with between .05 and .15 percent carbon and similar low proportions of other elements, and are thus almost pure iron. When other metals such as nickel, chromium, and molybdenum are added, "alloy" steels are obtained. Some alloy steels have large amounts of other metals; for example, some varieties of stainless steels may contain 25 percent of noniron metals.

In addition to steel, iron ore provides the iron content for ferroalloys and for the various types of finished iron products such as cast iron, grey iron, and malleable iron; it is also used as an additive in

open hearth furnaces. The demand for iron ore is thus determined by the demand for steel, which in the United States accounts for over 90 percent of the total use of iron ore; the remainder being used to produce the various iron products mentioned above. A tiny amount of iron ore (less than 1 percent of the total) is used for pigments and other nonmetallurgical purposes. The link between iron ore and steel, however, is an indirect one in current technology, for iron ore cannot be transformed directly into steel in one furnace. It must first be smelted to pig iron and then, in another furnace, refined to steel.

Pig Iron and Scrap

Pig iron (or primary iron) in current technology is the first stage in the transformation of iron ore to useful iron and steel materials. It is a crude metallic iron with a content of about 94 percent Fe, 3.0 to 4.5 percent carbon, and varying percentages of silicon, manganese, phosphorus and sulfur. The high carbon content makes it very hard and brittle, precluding its direct use for further manufacture. As a consequence a second stage is required to transform pig iron into a useful metal. Steelmaking and ironmaking furnaces (primarily the cupola furnace) do this job. The basic job of the steelmaking furnaces is to reduce the percentages of the other elements in pig iron (i.e., sulfur, phosphorus, silicon and carbon). When the carbon percentage is reduced to about .01 percent, steel is the end product; if higher carbon steels are required this is accomplished by carbon additions to the molten metal.

In modern practice all steelmaking furnaces which operate on high pig iron charges will receive the pig iron in a liquid state in order to lessen fuel requirements. The demand for iron ore therefore is directly derived from those furnaces in which primary iron is either the major or a substantial iron-bearing input. In the last two decades of the 19th century the bessemer furnace accounted for the major portion of iron ore demand since it operated on an almost complete hot iron charge. The open hearth furnace displaced the bessemer in the 20th century, in part because of its ability to operate on a mixed and variable hot metal/scrap charge,

and was until 1968 the major user of primary iron in the United States. Now and probably for the next three decades the basic oxygen furnace, which is most efficient on a 70 percent hot metal/30 percent scrap charge, will provide the largest source of demand for pig iron and thus for iron ore.

Scrap iron and steel, since they are virtually pure iron, are also inputs into iron and steel furnaces, as is shown in table 11. They are thus substitutes for primary iron and hence iron ore.

Table 11. Proportion of Iron and Steel Scrap and Pig Iron Used in U.S. Furnaces, 1969

Type of furnace	Scrap	Pig Iron
Basic oxygen converter.......	29.9	70.1
Open hearth..................	45.1	54.9
Electric.....................	98.6	1.4
Cupola.......................	83.7	16.3
Air..........................	69.5	30.5
Other[a].....................	99.4	.6

a/ Includes vacuum melting furnaces and miscellaneous processes.

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1969, p. 609.

Since the use of pig iron and scrap depends upon the kinds of steel and iron furnaces which are employed, it is necessary to forecast the proportion of raw steel and foundry products which will be made by each furnace type. The use of scrap and primary metal will depend upon the total cost of manufacturing raw steel from varying proportions of scrap and primary metal charges. Though it is possible to produce steel from scrap alone, as in the electric or open hearth furnace, it is theoretically and practically not possible for the United States or any of the major steel-producing countries to meet their steel requirements utilizing scrap as the sole input.

Such production is impossible because there is always some iron loss; i.e., the iron input into a steel furnace (or any other furnace) will always exceed the recoverable iron output. Second, the recovery of iron and steel scrap resulting from both the manufacture and obsolescence of steel and iron products is never complete. Thus there is always a loss of iron from the system which can only be made up by infusions of primary iron derived from iron ore. It is apparent that a nation's stockpile of iron and steel products, from which scrap is generated, can only grow if the rate of primary iron additions exceeds the rate of irrecoverable losses of iron and the rate of scrap withdrawals.1/

Stability of Pig Iron and Scrap Consumption in the Past

As a historical matter the total usage of pig iron and scrap (including revert scrap) has been a remarkably constant proportion of total metallic input in the last 25 years in the United States, as table 12 shows.

The percentage of pig iron consumption has increased slightly, by about 2 percent from 48 to 50 percent over this long period (a relative increase of about 4 percent). Purchased scrap (prompt industrial and obsolete scrap) has, however, shown much wider variation, and in the past 5 years has been about 6 percent below the rate of the 1940's and early 1950's (a relative decline of about 25 percent). Mill revert has increased by about 2.5 percent as a result of a greater proportion of more highly finished steel in total steel output and a higher proportion of killed ingots compared to rimmed ingots.

1/ We refer to obsolete scrap. Revert scrap and prompt industrial scrap which return to the steel plant within a year are simply recycled obsolete scrap and primary iron. Primary iron itself contains some scrap since blast furnaces use small proportions of such materials.

Table 12. Scrap Pig Iron Consumed, All Furnaces, 1945-69
(In percent)

Year	Purchased scrap	Mill revert	Total scrap	Pig iron
1945.............	23.2	28.3	51.5	48.5
1946.............	24.7	27.6	52.3	47.7
1947.............	24.5	26.2	50.7	49.3
1948.............	26.1	26.9	53.0	47.0
1949.............	23.6	27.1	50.7	49.3
1950.............	24.5	26.7	51.2	48.8
1951.............	25.5	26.2	51.7	48.3
1952.............	26.2	26.7	52.9	47.1
1953.............	23.3	27.6	50.9	49.1
1954.............	23.3	27.8	51.1	48.9
1955.............	24.4	27.0	51.4	48.6
1956.............	25.3	26.4	51.7	48.3
1957.............	21.5	27.2	48.7	51.3
1958.............	21.8	27.8	49.6	50.4
1959.............	22.6	29.1	51.7	48.3
1960.............	19.8	30.1	49.9	50.1
1961.............	19.5	30.0	49.5	50.5
1962.............	19.0	30.8	49.8	50.2
1963.............	20.2	30.5	50.7	49.3
1964.............	18.7	30.8	49.5	50.5
1965.............	19.7	30.7	50.4	49.6
1966.............	20.0	30.0	50.0	50.0
1967.............	21.5	28.0	49.4	50.6
1968.............	18.9	30.3	49.2	50.8
1969.............	19.4	30.7	50.1	49.9

Source: Institute of Scrap Iron and Steel, 1970 Yearbook, 31 ed., table 37.

One might suppose that such stability of pig iron is bound to continue into the next 30 years so that a forecast of 50 percent pig iron consumption is warranted. But several factors caution against such a view. First, the rapid increase in basic oxygen furnaces -- which we have forecast to account for 60 percent of total steel output in 1980 -- will increase the demand for primary iron as these furnaces replace the open hearth furnace, which uses about 55 to 60 percent hot metal compared to 70 percent for the basic oxygen furnace. Offsetting this to some extent is the more rapid growth of the electric furnace. However, some of this growth will be in electric furnaces using metallized ore (PRO) together with scrap.

Second, the greater use of continuous casting, though it will substantially reduce the total metallic input per unit of finished steel output, will lessen the proportion of revert scrap and thus will increase the proportion of pig iron plus purchased scrap taken together. Third, in the decades after 1980 the proportions of primary iron and scrap may be different than in 1970-80 as technological changes take place. It is not possible to predict the impact on primary iron and scrap without specifying the proportions of the furnace types and their charges. A naive forecast of 50 percent pig iron can easily be in error either way. A 5 percent increase in the proportion of primary metal, for example, on our 1980 forecast would lead to about a 9 million ton difference in standard ore requirement and to much larger differences in 1990 and 2000.

Pig Iron and Scrap Price Relationship

There exists for every technology a two-way relationship between the costs of input factors and the nature of technology. A specific technology is both an adaptation to and an influence on the costs of factors of production. Over a long period a specific technology changes in response to changes in costs of major input factors, and in so changing sets in motion changes in the supply and demand for these inputs. Hence the proportions of the basic oxygen and electric furnaces for the coming decades will be influenced by the cost of pig iron and scrap. Also the specific mix

of scrap and primary iron into each furnace type will be affected by the costs of these inputs.

The pig iron price in the United States is an administered price which changes only slowly. The price of scrap iron and steel responds very rapidly to short-run changes in supply and demand for scrap, unlike the pig iron price, which changes only with longer run factors. The scrap price since 1946 has fallen relative to the pig iron price (table 13). For very short periods the scrap price can approach or even exceed the pig iron price, as it did in the late 1940's and early 1950's as a result of pig iron capacity which was insufficient to meet peak steel output. But over the long run, iron ore and pig iron capacity will both increase and the scrap price will fall.

The prices of scrap and pig iron are not a clear index of their relative costliness in steel production. The amounts of other inputs such as fuel, power, labor, refractories, iron ore, ferroalloys, etc., bear no necessary relation either to the prices or amounts of pig iron and scrap used. Furthermore, the price of pig iron is not an accurate measure of either the variation in the cost of hot metal -- by far the major form of pig iron used in steel production -- or of its absolute unit cost. For one thing pig iron in its solid state entails a loss of heat compared to the molten metal, which is worth several dollars per ton in steel production. For another the market price of pig iron (which presumably contains capital cost) is not the economic price for an integrated steel firm. Such a firm, having blast furnace capacity, will find it profitable to use it to produce hot metal so long as its short-run marginal cost minus its indirect advantages plus its indirect disadvantages is equal to or less than the cost of purchased scrap.

Clearly at some price for purchased scrap, the balance of advantage will turn to scrap (for example, if scrap were a free good and hot metal remained at its present cost). Just where the equilibrium price of scrap is for the U.S. steel industry as a whole cannot easily be ascertained. Where it will be in 1980 and

Table 13. Relationship Between Pig Iron Price and Scrap Price, 1946-69

Year	Price per gross ton ($)		Scrap/pig iron price ratio
	Pig iron[a/]	Scrap[b/]	
1946..............	27.84	20.15	.72
1950..............	48.24	35.34	.73
1955..............	57.20	39.75	.69
1956..............	60.64	53.45	.88
1957..............	63.82	47.10	.74
1958..............	65.95	37.81	.57
1959..............	65.95	37.69	.57
1960..............	65.95	33.20	.50
1961..............	65.95	36.37	.55
1962..............	65.46	28.34	.43
1963..............	62.87	26.89	.43
1964..............	62.75	36.50	.58
1965..............	62.75	34.27	.55
1966..............	62.75	30.66	.49
1967..............	62.70	27.63	.44
1968..............	62.70	25.94	.41
1969..............	63.78	30.54	.48

a/ Monthly averages of pig iron composite price from quotations in _American Metal Market_.
b/ Monthly averages of #1 heavy melting steel are averages of Pittsburgh, Chicago, and Philadelphia from _American Metal Market_.

successive decades is an even more difficult problem. We can, however, gain insight into this question by a review of the past trends of prices and consumption of pig iron and scrap.

The price of scrap, relative to published pig iron prices, has decreased drastically since 1947 when the scrap price was approximately 10 percent higher than the published pig iron price, falling to about half the pig iron price in the past 5 years. In fact, the scrap price in 1969 was lower than in 1950: $30.54 compared to $35.34, as table 13 shows. The pig iron price increased from $48.24 to $63.78 during that period. Nevertheless, even with the drastic decline in the scrap price over this 19-year period, the balance of advantage has been slightly towards the use of hot metal in the production of steel, as table 12 shows. Hence even with the present low ratio of the scrap price to the pig price, the advantage of the basic oxygen furnace -- primarily Linz-Donowitz (L.D.) in the U.S. -- over all other furnace types must be considerable for major integrated steel producers, as its rapid increase shows.

The Supply Curve for Scrap

As the basic oxygen furnaces increase their share of total U.S. steel production the demand for purchased scrap will tend to fall, and, since the basic oxygen furnace uses about 70 percent hot metal, the future supply of scrap will increase as steel production from this furnace type increases. The decline in the scrap price over the past 25 years indicates that scrap supply relative to demand has been increasing. This can be seen directly by examining table 14, which shows U.S. pig iron consumption compared to scrap supply (i.e., the total of purchased scrap consumed plus net exports of scrap). As table 14 shows, pig iron consumption since 1946 has been more than twice as large as the consumption of purchased scrap (including net scrap exports). Thus the additions to the stock of iron and steel have been much greater than the withdrawals from it, and scrap availability -- that is, the amount of obsolete scrap which would be forthcoming if there were a demand

Table 14. Pig Iron and Scrap Consumption, Scrap Exports, Purchased Scrap Supply and Scrap Price, 1946-69

(In millions of net tons)

Year	Consumption				Net scrap exports	Purchased scrap supply	Scrap price a/ ($/gross ton)
	Total scrap	Mill revert	Purchased scrap	Pig iron			
1946...	49.5	26.1	23.4	46.5	.1	23.5	20.15
1950...	68.9	35.9	33.0	66.4	-.6	32.4	35.34
1955...	81.2	45.5	35.7	79.3	5.1	40.8	39.75
1956...	80.3	43.7	36.6	77.6	6.1	42.7	53.45
1957...	73.5	44.0	29.5	80.8	6.6	36.1	47.10
1958...	56.4	33.7	22.7	58.8	2.6	25.3	37.81
1959...	66.1	37.4	28.7	62.2	4.6	33.3	37.69
1960...	66.5	39.6	26.9	68.6	7.9	34.8	33.20
1961...	64.3	38.5	25.8	66.6	9.1	34.9	36.37
1962...	66.2	40.6	25.6	67.6	4.9	30.5	28.34
1963...	74.6	44.7	29.9	73.7	6.2	36.1	26.89
1964...	84.6	52.3	32.3	87.8	7.6	39.9	36.50
1965...	90.4	55.2	35.2	88.9	6.0	41.2	34.27
1966...	91.6	55.5	36.1	92.2	5.4	41.5	30.66
1967...	85.4	52.3	33.1	87.4	7.3	40.4	27.63
1968...	87.1	53.5	33.6	89.9	6.3	39.9	25.94
1969...	94.8	56.3	38.5	93.5	8.7	47.2	30.54

a/ Composite price (average of monthly prices at Pittsburgh, Chicago, and Philadelphia) of No. 1 heavy melting steel scrap.

Source: Institute of Scrap Iron and Steel, 1970 Yearbook, 31 ed., Tables 33 and 53.

for it -- has been growing continuously.[1/] In economic terms the scrap supply curve has shifted to the right; that is, a given price for scrap now would produce more scrap than that price 25 years ago. This can be seen if one compares the price change in purchased scrap from 1968 to 1969 and the corresponding change in scrap supply (which is a rough measure of the short-term scrap supply elasticity) with the change in scrap price from 1946 to 1969 and the corresponding change in scrap supply. Referring to the data in tables 13 and 14, this comparison shows the following:

	1968-69	1946-69
Scrap price change	+17.7	+51.6
Scrap supply change	+18.3	+100.9

The short-run scrap supply elasticity is 1.03, or approximately 1.0; the long-run supply elasticity is 1.94, or approximately 2.0.

The significance of these computations is that with increasing scrap availability over the coming decades the scrap price should fall, and scrap should become increasingly attractive as a metallic input.

Other Factors Favorable to Scrap -- Increasing Size of Electric Furnaces

The slow growth of electric furnaces from 1946 to 1970 is no indication of their future growth. The major steel companies were relatively small users of electric furnace capacity, employing these furnaces primarily for the production of alloy steel. The "minimills," which now account for about 4 million tons of capacity (virtually all in electric furnace steel), and

1/ In the 1960's the substantial imports of steel have also added to this supply of iron and steel products.

the smaller specialty steel companies were until recently the major users of electric furnaces. The large integrated steel companies producing tonnage steels require large furnaces with very high outputs. The growth in the sizes of open hearths (up to 400 to 500 tons per heat in the newest types compared with the prevailing 100 to 200 ton furnaces in 1946) and the basic oxygen furnaces which now are commonly over 200 tons per heat (about 250 to 300 tons per hour compared to about 50 to 75 tons per hour in the largest open hearth)1/ shows that significant economies of scale are obtained with larger steel furnaces.

Electric furnaces until about 1960 were rather small (50-ton heats for "large" electric furnaces). Now very large electric furnaces are being built: 250 tons per heat (about 50 to 75 tons per hour) is a common size for new furnaces, and Northwestern Steel and Wire Company is constructing a 400-ton electric furnace which will probably yield about 130 tons or more per hour. Thus one of the barriers to the use of electric arc furnaces by major integrated producers has been crossed. Improvements have also taken place in electric furnaces, in electrodes, refractories and control devices. There has also been a major improvement in scrap quality as the scrap industry has improved the uniformity and reliability of scrap through better elimination of contaminants. Scrap shredding equipment is particularly helpful with automotive scrap (junked vehicles) which is heavily contaminated with materials harmful to steel. Shredding equipment also will add to the scrap supply since junked automobiles are now not completely utilized.2/

1/ An open hearth heat takes about 8 hours; a B.O.F. heat, much less than 1 hour; and electric furnace heats, about 4 to 5 hours for large furnaces. The latter may be shortened with preheated scrap and with greater power input. One Midwestern company is operating a 150,000 KVA transfer capacity and producing up to 2,800 tons per day in 325-ton heats. This is less than 3 hours per heat. Only a few years ago, 30,000 KVA was normal. See Steel Facts, No. 208, October-November 1969, p. 3.

2/ It should be noted that our previous remarks on the increase in scrap availability took no account of the

The reasons for greater use of scrap in the future can be summarized as follows:

1. The long-term scrap price will decline relative to the costs of producing pig iron.

2. The quality of scrap will improve.

3. The availability of scrap will increase. We expect that by 2000 purchased scrap availability in the United States will substantially exceed 100 million net tons (i.e., more than double the purchased scrap supply in 1969).

4. The size and capacity per hour of the electric arc furnace will increase so that by 1980, 200-300 ton electric furnace heats will be commonplace.

As a consequence of these trends the relative advantage of using molten pig iron produced by blast furnaces will decline in future years. As of now, steelworks using only electric furnaces based on scrap are restricted in their tonnage to probably less than 500,000 tons per year, and serve specialty markets or local markets outside economical penetration by the larger steel producers. In the future the economical size of these plants will certainly increase to 1 million tons or more. The major steel companies are increasingly installing large electric furnaces as well as basic oxygen furnaces.

<u>Variability in the Metallic Inputs for Basic Oxygen Furnace -- Higher Scrap Charges</u>

The basic oxygen furnace of the L.D. type, which is the dominant variety in the United States as well as in the other major steel-producing nations, operates

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increase to the scrap stockpile of the large amount of imported autos and other iron and steel products. The United States is probably a net importer of iron and steel products as well as of steel itself.

at least cost on a 70 percent/30 percent charge of hot metal and scrap respectively. The present electric arc furnace operates on a virtually 100 percent scrap charge. In 1963, Stone, on the basis of theoretical analysis, predicted that L.D. furnaces would operate successfully on a 50 percent scrap charge.1/ Sir Henry Bessemer in fact received a patent in 1865 on a process of making steel or malleable iron from a solid scrap charge plus fuel. In 1949, at Linz, Austria, a 100 percent scrap charge was successfully smelted in an L.D. top blown oxygen converter.2/

In 1965 Wisconsin Steel Works successfully increased its scrap ratio from 27 percent to 34 percent; in 1966 Pittsburgh Steel produced two experimental heats with 61.7 percent scrap. T.E. Suess in 1957 received a U.S. patent for a process of smelting solid charges in an oxygen converter; and in 1966 R. Rinesch received a U.S. patent for a different process accomplishing the same thing. In addition, in 1966 Entremont and Moon of Armco showed on an experimental 30-ton furnace that a 100 percent solid scrap charge could successfully produce steel if the scrap is externally preheated and if solid fuels are supplemented in the converter.3/

These processes are not competitive with the conventional hot metal charge in the L.D. But the significant point is that much work attempting to utilize higher scrap charges in the basic oxygen furnace is being done and problems are being solved. The Kaldo furnace, another basic oxygen type, can utilize higher scrap charges (45 percent scrap), and although it is not as productive as the L.D. furnace when a suitable supply of hot metal is available, it is being utilized on a commercial scale both here and abroad. The conclusion to be drawn from this is that our estimate of a 70 percent hot metal charge for the entire 30-year period from

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1/ J.K. Stone, Iron and Steel Engineer, June 1963, pp. 67-78.
2/ See R.F. Rinesch, Journal of Metals, July 1962, pp. 497-501.
3/ J.C. Entremont and R.E. Moon, "All Scrap Charged B.O.F.," Journal of Metals, July 1969, pp. 53-56.

1970 to 2000 may be an overestimate of primary iron, particularly after 1980; hence it may overestimate iron ore requirements deriving from this source. Given the trend we expect in the scrap price, there will be a substantial inducement for the steel industry to extend the economical use of scrap in the L.D. furnace.

Primary Iron, the Blast Furnace and Prereduced Ore

Prereduced Iron Ore

In the previous section, the factors tending to increase utilization of scrap as a metallic input of electric arc furnaces have been identified. These factors will, we believe, result in a rate of increase in total electric furnace steel output from 1970 to 1980 greater than the historical trend which has prevailed from 1946 to 1970. However, new technologies of iron ore reduction now coming into use in the United States bypass the blast furnace and provide a "synthetic scrap" produced directly from iron ore that can be used by electric furnaces. This is prereduced iron ore, which is highly metallized, having an Fe content varying from 85 to 92 percent. We have referred to it as "PRO." In the literature it is called "super ore," "sponge iron" or "metallized" ore.

This ore can be produced by a wide variety of processes utilizing ordinary coals, natural gas, or gas made from oil or coal. These processes are generally referred to as "direct reduction," which in the 19th and early 20th century meant direct reduction of iron ore to steel in a single stage (single furnace). The term now refers to any process of reducing iron ore that is an alternative to the blast furnace. The technical literature contains many descriptions of such processes, some of which claim to be more economic than the blast furnace. (A direct reduction process -- HY-L -- has been used for many years in Mexico.) The end product takes a variety of physical forms ranging from spongy-looking material to pellets, nodules and densely compressed briquets. The iron content can vary. A low Fe content, such as one between 75 to 85 percent, will produce material for use by blast furnaces. A higher

Fe content, such as 92 percent, provides material which can be charged into electric furnaces, and some claim into basic oxygen furnaces. However, as our previous discussion shows, a solid scrap charge in the L.D. furnace, though possible, is not yet economic compared to a 70 percent hot metal charge. The raw material of the direct reduction processes should be high-quality lump ore or agglomerates, preferably pellets.

Some Implications of PRO

Direct reduction processes have very large implications for the future of the blast furnace and for the geographical shift of the U.S. steel industry. The link to coking coal is broken, and the combination of electric arc steelmaking furnaces and continuous casting opens the possibility of a larger proportion of steel being made in plants located closer to steel markets and, in the United States, of an increasing number of smaller plants.

The effect on the tonnage of imports of iron ore can be drastic, since the prereduced ore for electric arc furnaces will average about 90 to 95 percent Fe, a percentage that is much higher than the average Fe content of ore used in coke blast furnaces even though the latter will be using higher proportions of prereduced ore. The effects of PRO on total use of iron ore are not yet clear. Insofar as it displaces scrap input of the electric furnace, less scrap per ton of electric steel, and hence more iron ore, will be required. Counter to this is the possibility that PRO will make electric furnaces more attractive to large integrated steel producers, so that a greater amount of electric steel will be produced than would be the case if electric furnaces used complete scrap charges. This could increase the absolute amount of scrap. The net effect of these offsetting trends cannot presently be predicted with accuracy. In a subsequent section dealing with the share of raw steel production by furnace type, the details of our forecast of the share of total steel output by furnace type as well as the scrap/PRO hot metal composition of the metallic charge are given.

The effect of PRO on the use of coking coal is obvious. Coking coal used per ton of primary iron produced will decline as PRO use increases. Indeed, one of the great advantages of direct reduction is that it reduces the demand for coking coal and thus serves to keep its price from rising even faster than it has in the past several years.

The economics of the electric arc furnace based on prereduced ore (briquets, pellets, etc.) of high Fe content, probably used together with scrap, are now beginning to emerge. The consensus seems to be that this process will be competitive with the coke blast furnace/ basic oxygen furnace technology in the coming decade, and may well be the dominant method by the decade of the 1990's. One observer has suggested that by 1990 the electric furnace based upon scrap and prereduced ore would account for half the U.S. output of steel.1/ W.O. Hill, Vice President of Engineering, National Steel Corporation, stated that "The principle of direct reduction with electric furnaces is the only way we can afford to go."2/

The most convincing evidence of the probable truth of this view is of course the actual installations (and plants under construction), on a commercial scale, of electric furnace steelmaking using highly metallized ore as part of its charge in the United States, Canada, Mexico, Brazil, Japan and other countries.3/

1/ C.E. Sims, "What is Ahead in the Next 25 Years for Electric Furnace Steelmaking," paper read at Electric Furnace Conference of the American Institute of Mechanical Engineers, December 1967, at Chicago, Illinois.
2/ Iron Age, November 13, 1969, p. 72.
3/ Annual Review, Iron and Steel Engineer, January 1971, p. D28. Mexico has two plants, one in Vera Cruz, the other in Pueblo. One plant is being built in Sudbury, Ontario, and in New Zealand, and one is scheduled for completion in 1973 in Australia. See J.R. Miller in 1970 Yearbook, 31 ed., Institute of Scrap Iron and Steel, p. 88. Also, C.W. Court, "Iron Ore Policy in Australia," Blast Furnace & Steel Plant, December 1970, p. 875.

In the United States there are presently two commercial installations using metallized ores, one at Portland, Oregon, and the other at Georgetown, South Carolina. Other plants underway in the United States are one in Louisiana, located 30 miles upstream from New Orleans and using a 95 percent metallized pellet; an Armco plant at Houston with a capacity of about 350,000 tons of iron per year; and one underway at Mobile Bay, Alabama. The biggest U.S.-owned installation will supply the U.S. Steel Corporation plant in Baytown, Texas. This plant will use briquets (92 percent Fe) produced in Puerto Ordaz, Venezuela, by U.S. Steel in a fluidized bed process employing Venezuelan natural gas. The initial scale in Venezuela is approximately 1 million tons of PRO ranging from 85 to 92 percent Fe; this is now the largest direct reduction plant in the world.

The Government of Venezuela is also building a direct reduction facility for its own needs. One can expect that the C.V.G. (the Venezuelan agency which owns and operates the iron and steel plants, iron mines and other industrial facilities owned by the Government of Venezuela in the Province of Guayana) will expand these facilities in order to export higher valued PRO in place of iron ore. The natural markets for Venezuelan PRO are of course primarily in the United States. Even the gulf coast, with its abundant supplies of natural gas, seems not to be competitive with Venezuelan PRO, since the U.S. Steel Corporation chose to build its ore reduction plant in Venezuela rather than in Texas. (The electric steel furnaces using these briquets and the continuous casting plant are in Texas.)

Even if gas were as cheap on the gulf coast as in Puerto Ordaz (which is only 100 miles from large gas fields, about the same distance from the iron ore fields, and practically adjacent to the 3.5 million kw. hydro plant on the Caroni River), the savings in transportation of 85 to 92 percent Fe briquets compared to 65 percent pellets or lump ore would be considerable. We can therefore expect that in the future the tonnage of Venezuelan iron ore imported by the United States will decline relative to the tonnage of iron content of these imports.

Scale of Plant Using PRO and Electric Furnaces and Time Phasing

The general consensus is that the blast furnace/ basic oxygen furnace technology in the production of steel must give way to the direct reduction electric furnace, primarily because of the increasing shortages of coking coal and the consequent increase in its price relative to electric power and other fuels. However, no one believes that this displacement will reach serious proportions until the mid-1980's at the earliest. Certainly the steel companies in the major steel-producing countries are counting on the blast furnace/ basic oxygen furnace to be the dominant technology.

Larger sized blast furnaces continue to be built. The first post-war generation of these furnaces, particularly in Japan, were 4,000 to 5,000 ton per day furnaces. The second generation furnaces built in the past few years and currently under construction in Japan, France, West Germany and the U.S.S.R. (though not yet in the United States) are 7,500 to 11,000 tons per day.1/ Such furnaces will doublessly be operating for the next 20 years. We may expect, however, that there will probably be no third generation of blast furnaces. Blast furnace technology is an old one which is highly developed, and the efficiency (of the latest types) is close to the maximum available, even though improved iron ore feeds (PRO) and other measures will achieve further economies in the use of coke. On the other hand, the direct reduction processes are at the very beginning stage of their technological development, so that future increases in their efficiency and size will without doubt be very much greater than future improvements in the blast furnace. By 1980 and thereafter we may expect that direct reduction installations will increase rapidly, while new blast furnace installations will fall substantially.2/

1/ Usinor is building an 11,000+ ton furnace in Dunkerque, France, the largest so far noted, though the latest, Japanese and West German furnaces are about the same size.
2/ The United States, however, has not yet achieved an average size of blast furnace equal to 5,000 tons per

Figures 2 and 3, based upon British prices, show the break-even level of the SL/RN/arc furnace route (SL/RN is a coal-based rotary kiln direct reduction process) with the blast furnace/basic oxygen furnace route, computed for varying prices of electricity and coking coal.

Figure 2 is based on the use of high-quality lump ore (67 percent Fe) in the SL/RN process, and figure 3 is based on agglomerated ores of equal iron content.

Table 15 (based on figures 2 and 3) summarizes the costs of steel to continuous casting (i.e., raw liquid steel) at which the SL/RN/arc process is equal to the blast furnace/basic oxygen furnace route, and the tonnage break-even points as the price of electricity varies. The table chooses the most favorable condition for the blast furnace shown in the figures, i.e., a coking coal price of $16.80 per ton (delivered to the plant site). These costs are not too far off U.S. conditions. The coking coal price is higher than what U.S. steel producers pay, and similarly the ordinary coal price assumed in the charts is also higher. These are offsetting assumptions for U.S. conditions, so that we may accept the comparisons as being first approximations of U.S. conditions. It should be noted that at tonnages lower than the break-even tonnage the direct reduction processes will be cheaper than the blast furnace processes; at higher tonnages they will be more expensive.

Since most ores used will be agglomerates, figure 3 is the more likely condition. Even at the lowest price of electricity (.5¢/kwh) the largest direct reduction/arc plant will be more expensive than the classic method at tonnages beyond 2.25 million tons of steel per year. However, this assumes a coking coal price of $16.80 per ton. We can expect then that during the 1970's steel plants using a PRO/electric arc

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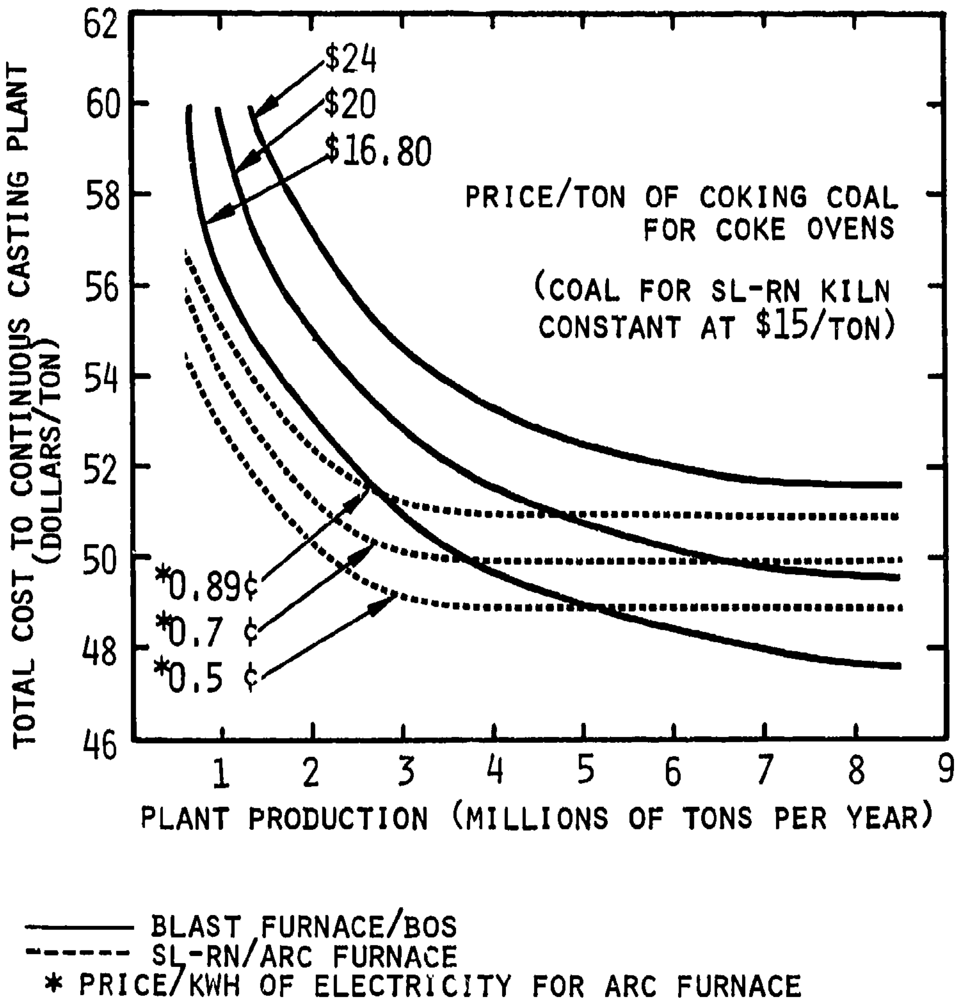
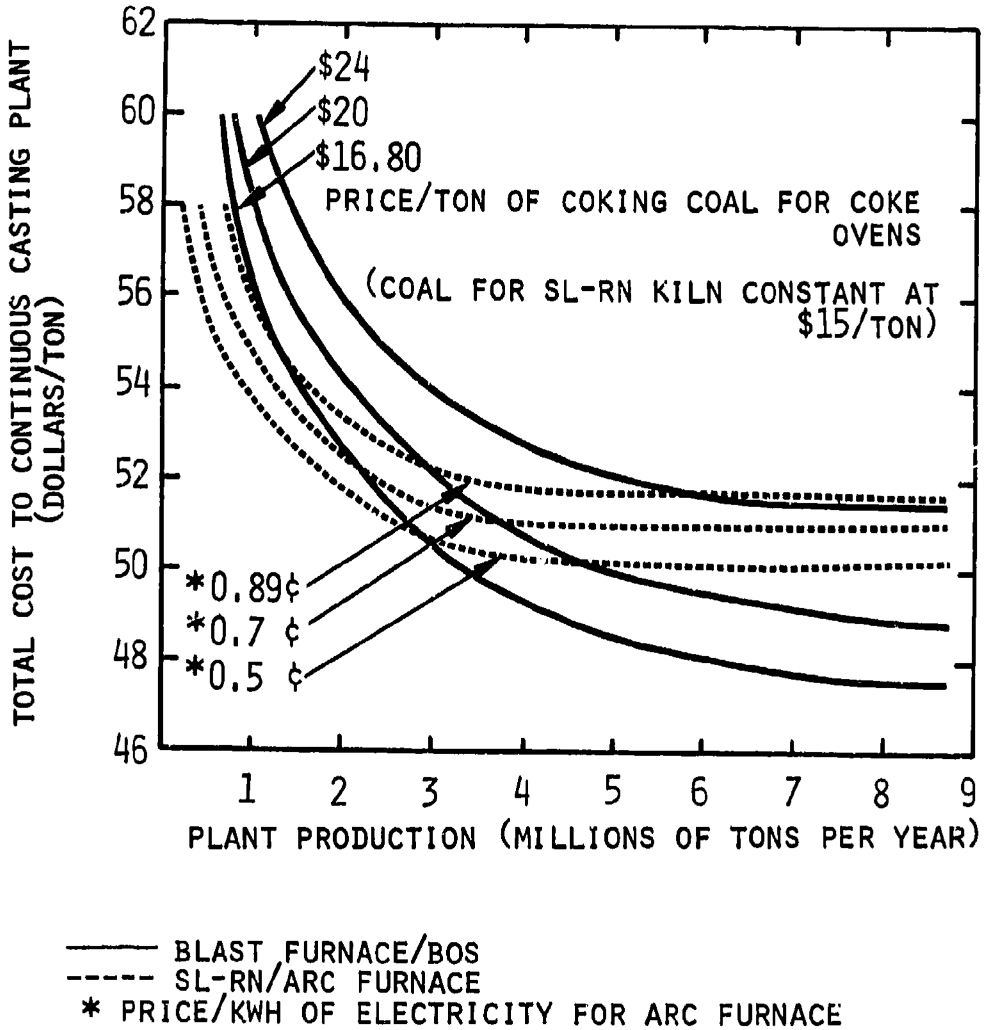
day capacity. Given the direct reduction technology it is likely that the United States will not be so heavily committed as Japan to very large blast furnaces.



Source: W.F. Cartwright, 'The Economic Survival of the Blast Furnace,' Journal of the Iron and Steel Institute (U.K.), February 1971, vol. 209, part 2, p. 93.

FIGURE 2. TOTAL COSTS OF BLAST FURNACE/BOS COMPARED TO SL/RN/ARC FURNACE, USING ORE IN KILNS NOT REQUIRING AGGLOMERATION



Source: W.F. Cartwright, 'The Economic Survival of the Blast Furnace,' Journal of the Iron and Steel Institute (U.K.), February 1971, vol. 209, part 2, p. 93.

FIGURE 3. TOTAL COSTS OF BLAST FURNACE/BOS COMPARED TO SL/RN/ARC FURNACE, USING ORE IN KILNS REQUIRING AGGLOMERATION

Table 15. Comparison of Raw Liquid Steel Costs for Direct Reduction/Arc Process and Blast Furnace/ B.O.F. Process

Electricity price (cents/ Kwh)	Figure 2		Figure 3	
	Break-even cost of steel ($/ton)	Break-even tonnage (million tons/year)	Break-even cost of steel ($/ton)	Break-even tonnage (million tons/year)
0.89....	51.50	2.75	55.00	1.25
0.70....	50.50	3.50	53.00	2.00
0.50....	49.50	4.25	51.00	2.25

process are likely to be small plants (less than 1 million tons), particularly as there are few locations in the United States at which electric power can be purchased at rates below .8 to .9 cents per kwh.1/

Cartwright's conclusions from his analysis are as follows:

1. The blast furnace/B.O.F. combination is likely to remain the principal method for making crude steel in the major steel-producing countries.

2. The direct reduction/electric arc furnace route will find a growing place in markets where there is a demand for 1 1/2 million tons of steel or less.

3. In the long-term future "the break-even point as regards size...will move inexorably in favor of direct reduction. This situation may be reached sooner than expected, even in countries where conditions now favor the blast furnace."2/

1/ However, the very favorable conditions which exist in Venezuela for the low-cost production of PRO may permit much larger installations for U.S. Steel and Bethlehem, which have large Venezuelan ore reserves.
2/ W.F. Cartwright, op. cit., p. 94.

4. "The technology of direct reduction will not stand still. Improvement, together with a growth in unit size...will confer economies of scale" making direct reduction processes more competitive in the future than they are now.1/

The effect on the demand for iron ore does not depend upon whether the blast furnace will ultimately be displaced, but on the mix of scrap and PRO in the two major furnace types which from about 1975 will dominate U.S. steel production; that is, the basic oxygen furnace and the electric arc furnace. As for the former, the evidence is clear enough that significantly increased solid charges above 30 percent, either of scrap or PRO, will not take place by 1980. What happens thereafter depends critically upon the cost of coking coal in the United States and upon technical advance in adapting the L.D. furnace to higher percentages of solid charges. Stone may well be correct in predicting a 50 percent solid charge for basic oxygen furnaces, but we do not expect such a high proportion to be ordinary practice until the decade of the 1990's. As for electric furnaces, we expect that a much more rapid use of PRO will take place, so that by 1980 a significant proportion of U.S. electric furnaces will be operating on PRO-scrap charges.

The Share of Raw Steel Production by Furnace Type, 1980-2000

1980 Share

Table 16 shows the total tonnage by steel furnace type from 1947 to 1970, as well as the percentage of total steel output for each furnace type. It is apparent that the open-hearth process, like the bessemer process which preceded it, is being phased out. The forecasting problem is how fast it will be displaced by the basic oxygen furnace and electric arc process. Since we do not know the plans of the steel producers

1/ Ibid.

Table 16. Production of Steel Ingots and Steel for Castings by Furnace Type, 1947-70

(In millions of net tons)

Year	Total	Open hearth		B.O.F.		Electric		Bessemer	
		Amt.	Pct.	Amt.	Pct.	Amt.	Pct.	Amt.	Pct.
1947......	84.9	76.9	90.6	--	--	3.8	4.4	4.2	5.0
1948......	88.6	79.3	89.5	--	--	5.1	--	4.2	--
1949......	78.0	70.2	90.1	--	--	3.8	--	3.9	--
1950......	96.8	86.3	89.1	--	--	6.0	6.2	4.5	4.7
1951......	105.2	93.2	88.6	--	--	7.1	--	4.9	--
1952......	93.2	82.8	88.9	--	--	6.8	--	3.5	--
1953......	111.6	100.5	90.0	--	--	7.3	--	3.9	--
1954......	88.3	80.3	91.0	--	--	5.4	--	2.5	--
1955......	117.0	105.4	90.0	.3	--	8.1	6.9	3.3	2.8
1956......	115.2	102.8	89.3	.5	--	8.6	--	3.2	--
1957......	112.7	101.7	90.2	.6	--	8.0	--	2.5	--
1958......	85.3	75.9	89.0	1.3	--	6.7	--	1.4	--
1959......	93.4	81.7	87.4	1.9	--	8.5	--	1.4	--
1960......	99.3	86.4	87.0	3.3	3.4	8.4	8.4	1.2	1.2
1961......	98.0	84.5	86.2	4.0	4.0	8.7	8.8	.9	--
1962......	98.3	83.0	84.4	5.6	6.7	9.0	9.2	.8	--
1963......	109.3	88.9	81.3	8.5	7.8	10.9	10.0	1.0	--
1964......	127.1	98.1	77.2	15.4	12.2	12.7	10.0	.9	--
1965......	131.5	94.2	71.6	22.9	17.4	13.8	10.5	.6	--
1966......	134.1	85.0	63.4	34.0	25.3	14.9	11.1	a/	--
1967......	127.2	70.7	55.6	41.4	32.6	15.1	11.9	a/	--
1968......	131.5	65.9	50.1	48.9	37.1	16.8	12.8	a/	--
1969......	141.3	60.9	43.1	60.2	42.6	20.1	14.3	a/	--
1970......	131.3 b/	48.6	37.0	63.0	48.0	19.7	15.0	--	--

a/ Included with open hearth.
b/ Preliminary for 1970.
Source: American Iron and Steel Institute.

over the next 10 years with respect to the open hearth process (and it is doubtful that they know in detail how rapidly they will phase out the open hearth in the next 10 years), reliance must be placed on trends shown by the statistics in table 16. Fitting long-term time trends to each of the steel processes separately will of course not be satisfactory since they are not independent. We deal with interrelated, nonlinear growth and decline curves in each of the furnace types, and we must judge what the asymptotic values are and the rates of approach to these values.

J.R. Miller, former United Nations steel expert and an internationally known consulting steel engineer, has given the estimates shown in table 17.

Table 17. Amount and Percent Share of Total U.S. Raw Steel Output by Furnace Type, 1970-99

(In millions of net tons)

Year	Oxygen		Electric		Open hearth		Total (amount)
	Amount	Pct.	Amount	Pct.	Amount	Pct.	
1970....	61.4	44.2	18.9	13.6	58.7	42.2	139
1[illegible]90....	99.6	55.0	44.3	24.5	37.1	20.5	181
19[illegible]0....	126.6	60.0	67.5	32.0	16.9	8.0	211
19[illegible]..	153.1	62.0	88.9	36.0	5.0	2.0	247

Source: Derived from table 2 of a paper presented by J.R. Miller to the Institute of Scrap Iron and Steel, 42nd Annual Convention, Los Angeles, January 18, 1970, and reprinted in the <u>1970 Yearbook</u> of the Institute, p. 86.

The forecast made in January 1970 (see table 18), overestimated the percentage of the open hearth. The 1970 value for the open hearth is 37 percent compared to Miller's 42 percent (see table 16). As a consequence in 1970 his oxygen and electric furnace shares are

below the actual 1970. The error appears to be largely due to the overestimate of actual ingot output, which was only 131 million tons in 1970 compared to Miller's estimate of 139 million tons. As can be seen by comparing tables 16 and 17, Miller's absolute tonnages for the oxygen process and the electric processes are much closer, though they are also underestimated.

We believe that the open hearth process is being phased out more rapidly than Miller's estimates show. In the past 10 years the open hearth has declined from 86.2 percent of total steel output to 37.0 percent, or a relative decline of 57 percent over the 10-year period and an average yearly decline of 5.7 percent. We see no reason why it should not continue to decline at least at this rate; therefore, we project the open hearth share of total steel output in 1980 at 15 percent, a decline of 60 percent from its 1970 share of 37 percent.

In an article in the Iron and Steel Engineer of June 1970, R. Tietig and R. J. Kuhl (both of the Kaiser Engineering Division of Kaiser Industries) describe a method to predict the changes in steelmaking processes, i.e., the amount of basic oxygen furnace, electric furnace and open hearth steel which will be made at assumed levels of steel production and continuous casting for the next 10 or 15 years. The first step in their method is to select nine open hearth shops from the entire steel industry which they consider will be "probable," i.e., probably used for minimum open hearth production. These nine plants have an open hearth annual capacity of 24.5 million tons. Another seven open hearth shops with a capacity of 9.9 million tons are considered "possible," so that maximum open hearth capacity 10 years hence is 34.4 million net tons. Their open hearth plants are shown in table 18.

Their procedure basically consists of determining the metallics which would be required at various assumed levels of steel production and assumed levels of continuous casting. We are given yields by furnace type, ratios of use of hot metal and scrap, and a given open hearth production level (maximum or minimum). Since purchased scrap is taken as a constant percentage of total steel output (.163), as is plant-generated

Table 18. Probable Future Open Hearth Capacity

Plant	Average number of furnaces operating in shop	Average tons per furnace hr. shop	Hot metal in charge (percent)	Estimated annual capacity (net tons per year)
	"Probable" for minimum open hearth production			
A.........	5.4	36.8	61.0	1,740,000
B.........	5.9	69.7	67.1	3,600,000
C.........	5.9	43.5	51.2	2,250,000
D.........	9.8	35.0	53.0	3,005,000
E.........	8.2	54.1	64.6	3,885,000
F.........	7.5	32.7	54.9	2,150,000
G.........	9.9	40.3	59.8	3,495,000
H.........	9.6	21.7	53.1	1,825,000
J.........	6.7	43.5	55.5	2,550,000
Subtotal.				24,500,000
	"Possible" additional open hearth capacity			
K.........	3.0	39.0	57.9	1,025,000
L.........	6.6	33.5	58.0	1,900,000
M.........	3.2	40.5	46.8	1,140,000
N.........	3.0	53.8	47.9	1,415,000
P.........	5.4	15.7	59.1	745,000
R.........	7.2	27.0	52.2	1,705,000
S.........	12.4	18.1	60.0	1,970,000
Subtotal.				9,900,000
Total...				34,400,000

Source: R. Tietig and R.J. Kuhl, Iron and Steel Engineer, June 1970.

scrap (.320), the total scrap availability for each furnace is solved algebraically to yield the share of basic oxygen and electric furnaces.

One of their major conclusions is that increased amounts of continuous castings will lead to higher basic oxygen furnace production since less revert scrap is available and purchased scrap is a fixed proportion of raw steel; hence only hot metal can make up the gap. On the other hand, if PRO is used, electric furnace output will increase since it substitutes for the needed scrap. The critical assumption is the constancy factor assumed for purchased scrap availability. We disagree with this assumption for reasons already given in the section entitled "Pig Iron and Scrap," and do not believe that electric furnace output in 1980 will even come close to the limit of scrap availability. Nevertheless we believe their selection of the open hearth shops is a useful first approximation to the 1980 open hearth output. As it turns out, their minimum open hearth value of 24.5 million tons is equal to 14.9 percent of our forecast for raw steel production of 164.4 million tons in 1980. This is practically identical with our estimate for open hearth production of 15 percent of total output in 1980.

If we take the values on Tietig and Kuhl's Chart VI, based on using 10 percent of the total electric furnace scrap requirements as metallized ore (PRO) and minimum open hearth production, we have the shares by furnace type at the ingot equivalent forecast in this report for 1980 (i.e., 169 million tons) and given in table 19.

Share for 1990 and 2000

By 1990, no open hearth furnace in the United States will be less than 25 years old, and most of the existing open hearth shops in current steel plants will have been dismantled and replaced by basic oxygen and electric furnaces. Those that remain are likely to be the largest furnaces (which are also the newest) and which use the least space per ton of output. We have projected a somewhat more rapid decline for the decade

Table 19. Steel Ingot Output and Percent by Furnace Type, 1980

Furnace type	Tietig, Kuhl[a]		This report	
	Mil. net tons	Percent	Mil. net tons	Percent
Basic oxygen..	104.0	61.3	101.2	60.0
Electric......	41.0	24.2	42.2	25.0
Open hearth...	24.5	14.5	25.3	15.0
Total........	169.5	100.0	168.7	100.0

a/ Tietig and Kuhl, op. cit., p. 84. Absolute values read from Chart VI are only approximate, and thus differ slightly from our totals.

1980-90 than in 1970-80 -- a two-thirds decline from 15 percent of total U.S. output in 1980 to 5 percent in 1990. Miller's projection (table 17) of the open hearth for 1990 is 8 percent. If we select plants B, E and N in table 18 as meeting the criteria of the largest furnaces (all having an average output of over 50 tons per hour) as those most likely to survive, the total capacity of these plants is approximately 9.0 million tons, which on the basis of our projection of raw liquid steel for 1990 is 4.9 percent. Of course we have no way of knowing which open hearth shops will survive into 1990. The basic argument we rely on is that the rate of displacement from 1980 to 1990 will be at least as rapid as in the prior decades since all the economies of using basic oxygen and electric furnaces relative to the open hearth will be even greater than they are now or will be in the next 10 years.

Unlike Miller, who expects the basic oxygen furnace's share to be 60 percent in 1990, we project the basic oxygen furnace at 65 percent of total output in 1990, the peak share of this furnace type. We believe that U.S. blast furnace capacity and output will be at its peak during the mid-1980's to mid-1990's, and that the basic oxygen furnace, the most efficient furnace

to utilize hot metal, will also be at its peak.1/ From the mid-1980's on, direct reduction, together with the electric furnace, will be growing rapidly as has previously been discussed. Table 20 consolidates the percentage estimates of Miller, Tietig-Kuhl, and this report.

Table 20. Forecasts of Total Raw Steel Output by Furnace Type, 1980-2000

Furnace type	Basic oxygen	Electric	Open hearth
1980			
Miller........	55.0	24.5	20.5
Tietig-Kuhl...	61.3	24.2	14.5
This report...	60.0	25.0	15.0
1990			
Miller........	60.0	32.0	8.0
This report...	65.0	30.0	5.0
2000			
Miller........	62.0	36.0	2.0
This report...	60.0	38.0	2.0

Metallic Inputs by Furnace Type

Table 21 shows in absolute amounts the consumption of pig iron and scrap by the major iron and steel making furnaces from 1959 through 1969. The total of these two iron-bearing materials together with PRO -- which is only now coming into use and is thus not included in the past statistics -- is what we define as the metallic charge. Small amounts of other iron-bearing materials such as ferroalloys and iron ore are also charged into the furnaces, contributing some Fe

1/ The reason for this view is the fact that the bulk of U.S. blast furnaces are now undersized and less efficient than Japanese and West European furnaces. Over the next 15 years the U.S. steel industry will be catching up in this phase of technology.

Table 21. U.S. Consumption of Pig Iron and Scrap by Furnace Type, 1959-69
(In millions of net tons)

Year	Open hearth		Basic oxygen		Electric		Bessemer		Cupola		Air		Blast
	Scrap	Pig	Scrap	Pig	Scrap	Pig	Scrap	Pig	Scrap	Pig	Scrap	Pig	Scrap
1959......	38.6	51.3	--	--	10.3	.39	--	--	10.8	4.5	1.3	.25	3.2
1960......	39.6	55.3	--	--	9.9	.37	--	--	10.0	3.8	1.1	.21	3.6
1961......	37.9	54.6	1.4	3.6	10.1	.28	.11	.98	9.5	3.4	1.0	.18	3.6
1962......	36.8	54.5	1.8	5.0	10.9	.24	.10	.79	10.7	3.4	1.2	.19	3.8
1963......	40.6	57.3	2.8	7.1	12.9	.21	.16	1.60	11.9	3.6	1.3	.18	4.3
1964......	43.9	65.2	5.5	12.4	14.9	.32	.12	.95	13.4	3.7	1.4	.17	4.8
1965......	43.2	61.5	7.8	18.5	16.7	.39	.08	.65	14.8	3.8	1.5	.17	5.1
1966......	39.3	55.5	11.4	27.8	18.0	.29	.07	.33	15.3	3.7	1.6	.15	5.2
1967......	33.0	46.4	13.9	33.6	18.0	.38	.04	.09	13.9	3.2	1.1	.15	4.7
1968......	31.6	40.1	16.1	39.3	19.6	.52	--	--	14.8	2.9	n.a.	n.a.	4.3
1969......	30.7	37.4	19.8	46.4	23.8	.33	--	--	15.0	2.9	.21	.09	4.8

Table 22. Percentage of Scrap and Pig Iron of Total Iron Input by Furnace Type, 1959 and 1965-69

Year	Open hearth		Basic oxygen		Electric		Cupola		Air	
	Scrap	Pig	Scrap	Pig	Scrap	Pig	Scrap	Pig	Scrap	Pig
1959.........	42.9	57.1	n.a.	n.a.	98.8	1.2	70.6	29.4	82.3	17.7
1965.........	41.3	58.7	29.7	70.3	97.7	2.3	79.7	20.3	89.8	10.2
1966.........	41.5	58.5	29.1	70.9	98.4	1.6	80.5	19.5	91.4	8.6
1967.........	41.6	58.4	29.3	70.7	97.8	2.2	81.3	18.7	88.0	12.0
1968.........	44.1	55.9	29.1	70.9	97.5	2.5	83.6	16.4	n.a.	--
1969.........	45.1	54.9	29.9	70.1	98.8	1.2	83.8	16.2	n.a.	--

input.[1/] They are excluded in this report. Table 22 shows the percentage of pig iron and scrap used by each of the major furnace consumers.

Table 22 shows no trends other than in the iron foundry furnaces. In the cupola and air (virtually obsolete) furnaces the decrease in the use of pig iron is marked. The reasons for this lie in the declining scrap/pig iron price ratio previously noted, as well as in the difficulties during the past several years of obtaining free market iron, caused by the very great increase in basic oxygen furnace hot metal requirements. This probably accounts for the small increase in the open hearth scrap proportion in 1968 and 1969.

Forecasts of Metallic Input, 1980-2000

In accordance with the preceding information we have forecast the scrap/pig iron percentages for 1980-2000 as shown in table 23.

Table 23. Forecasts of Metallic Input by Furnace Type, 1980-2000

Furnace type	Pig iron	Scrap
Open hearth...........	58	42
Basic oxygen..........	170	30
Electric..............	1.5	98.5
Cupola................	.15	.85

As we have said, metallized ore of approximately 92 to 95 percent Fe will be increasingly used in all

1/ Iron ore in current and past practice constituted about 3 percent (by weight) of the open hearth charge. However, in view of the rapidly declining open hearth share, by 1980 iron ore used by the open hearth will be less than 1 million tons.

furnaces. Since the Fe content of this material is approximately the same as pig iron and since both are derived directly from iron ore, with approximately the same Fe output per ton of Fe (in the ore) input, there will be little effect on the level of iron ore requirements if pig iron (hot metal) or PRO is charged into the furnaces. The only effect on iron ore requirements will result from changes in the scrap percentage. Since the basic oxygen furnace is so prolific a producer of steel, every effort will be made to increase its ability to use a higher proportion of solid charge. If this consists of PRO (assuming that it will be cheaper than hot metal) then an optimal mix of hot metal and PRO, higher than the 30 percent scrap now used, may well reduce the rate of expansion of electric furnaces using a scrap-PRO charge or an all-scrap charge. In this eventuality a higher iron ore requirement will result.

We have chosen to project the same ratio for the basic oxygen furnace to the year 2000. As for the open hearth, by 1990 it will be only 5 percent of total output, and only 2 percent by 2000, so that even significant changes in primary iron input either way will have little effect on total iron ore requirements.

The situation is quite different with the electric furnace. This furnace will be the primary user of PRO from 1970 to 1980 and an important user thereafter. The proportion of pig and scrap shown in table 23 is what we expect in only one part of the steel industry using electric furnaces. It consists primarily of what we have called "mini-mills," specialty producers (primarily alloy steels, i.e., firms such as Allegheny-Ludlum, Cyclops, Copperweld, etc.), and fairly substantial inland producers such as Northwestern Steel and Wire. Of the major steel producers, only Republic Steel and Armco have had a significant tonnage of electric furnace capacity.

We expect that most of this group of nonintegrated electric furnace steel producers will continue on the virtually all-scrap charge shown in table 23. However, we expect that the major steel producers will have added substantial capacity in electric furnaces using PRO-scrap charges by 1980. (See appendix table 4

for a list of electric furnace facilities being added by the major integrated producers and the large non-integrated producers.) In particular the gulf coast and the Atlantic coast are likely areas for such production because of their easy access to rich foreign ore, including Venezuelan metallized ore (C.V.G. ore as well as U.S. Steel and Bethlehem metallized ore). Further, we believe that some direct reduction plants utilizing ordinary coal (noncoking) as in the SL/RN process will be built in the Pittsburgh area (including Wheeling and Weirton) and will use both Lake Superior pellets as well as high-grade foreign pellets.1/

Our forecast for the electric furnace share of output for 1980 is 25 percent. The problem is to determine a basis for projection of electric furnaces utilizing substantial PRO inputs as well as scrap and those which, as of now and in the future, will utilize complete scrap charges. We have used the average of the electric furnace's share of total output for the past 4 years, shown in table 17, of approximately 18 percent. In short we have assumed that the all-scrap based electric furnace output will have a share of 18 percent of total steel output in 1980; the difference between our forecast of 25 percent and 18 percent represents new electric furnace growth. This growth will be primarily by large integrated producers utilizing very large electric furnaces based upon a PRO-scrap charge, and will in part replace some of the open hearth capacity which these producers will be phasing out between 1970 and 1980.2/

For 1990 and 2000 we have projected further increases in the proportion of PRO-based electric furnaces by the large integrated companies compared to the nonintegrated segment of the steel industry. By 1990 the

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1/ We think coal will be cheaper than natural gas in these areas.
2/ This trend has begun. For the first time, Inland, an electric steel furnace producer, is replacing its open hearth shop with two basic oxygen furnaces and two large electric furnaces. Bethlehem, U.S. Steel, Armco and Republic have also added large electric furnace installations.

direct reduction process will have had 15 years of commercial production and development, and significant improvements will have been achieved. By 2000, we expect it to increase even further and cut into the share of the basic oxygen furnace. In the last two decades of the century the direct reduction/electric furnace technology will be widespread in all U.S. steel-producing regions.1/ As a consequence of these considerations the nonintegrated specialty steel producers will lose in share, though not in absolute output. This is because widespread use of PRO-scrap technology will serve to keep scrap at prices attractive enough to enable smaller plants serving restricted markets to have the same opportunity to operate profitably as they have now.

Metallic Input of the PRO-Scrap Electric Furnace

No conclusive evidence is yet available on what an optimal mix of PRO-scrap will be in the electric furnace steel process. Because of its greater physical uniformity, a 100 percent metallized ore may melt more easily and faster than an all-scrap charge. On the other hand, the effect of greater gangue and unreduced FeO content of the metallized ore will force a rise in power consumption and heat time. What seems to be clear is that a mixture of both will probably give faster heats and lower power consumption than either used as the sole charge. Of course the critical factor is the difference in the price of scrap compared to metallized ore at a specific plant site. Though current estimates range from about $47 to $51 per long ton (including fixed charges of $10 per ton) for a 200,000 ton per year operation to about $39 to $41 for a 1 million ton per year plant, Miller believes that by the late 1970's it is possible that PRO may fall to about $33 per ton, particularly for steel plants owning their own ore. Even if scrap is $5 to $6 per ton lower, he believes that an electric furnace shop using 40 percent PRO, 48 percent purchased scrap and 12 percent revert scrap would be cheaper than the current operation based on all

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1/ This will be facilitated by the increase in nuclear power plants in all regions of the United States by 1990.

scrap.[1] In any event, since costs are speculative, we have estimated the charge of PRO-scrap (excluding revert, which is a combination of both) for integrated producers to be 55 percent PRO and 45 percent scrap. Our projection assumes a lower rate of PRO use per ton of electric furnace output, primarily because we believe that the nonintegrated part of the electric furnace industry will continue to operate on a virtually all-scrap charge (98.5 percent) even through 2000. However, the divergence between Miller's estimates and our own for 1980 are small. Table 24 is our forecast of electric furnace output for 1980-2000 for the two segments of the industry. Table 25 shows our estimates of PRO consumption in the United States for 1980, 1990, and 2000, as compared with Miller's estimates.

Table 24. Percentage Share of Total Steel Output by Integrated and Nonintegrated Electric Furnace Producers

Producer	1980	1990	2000
Integrated.......	7	15	25
Nonintegrated....	18	15	13

Table 25. Estimated Total PRO Consumption in the United States

(In millions of tons)

Year	This report	Miller[a]
1980..............	7.3	9.0
1990..............	17.4	31.3
2000..............	35.0	44.3

a/ Adjusted to our steel forecast.

1/ J.R. Miller, op. cit., pp. 88-91.

If Miller's estimates of PRO use are correct, the estimated iron ore requirements of this report would appear to be too low for the period after 1980. On the other hand, it should be noted that a very conservative assumption has been made in the forecast that the basic oxygen furnaces will continue to operate on a 70 percent primary iron (hot metal or PRO), 30 percent scrap charge through the period 1980-2000. We have made this assumption because as of now no commercial installation is routinely operating basic oxygen furnaces on all-scrap charges or with charges substantially higher than 30 percent scrap. However, we know that Kaldo furnaces are being used in Western Europe with 40 to 45 percent scrap charges on a routine basis,1/ and some in the United States are also being used. In 1970, Armco, following the work of its engineers Entremont and Moon (which has previously been noted, and in which 99 out of 100 20-ton heats based on preheated solid scrap charges were applied to customer orders), produced a 160-ton heat from a 200-ton basic oxygen furnace at its Middleton plant in 1 hour. Later operations gradually brought the peak output up to the 200-ton capacity of the furnace. Some heats were blown in less than 20 minutes.2/ No comparative cost figures are available. But it seems certain that with all the interest and work, steel producers do look forward to a time when hot metal will be a smaller component of the basic oxygen furnace charge, and solid charges -- both PRO and scrap -- will be a larger component. A shift of 5 percent in scrap use from 30 to 35 percent in the basic oxygen furnace charge would lower the iron ore requirements we have forecast by 7.6, 9.6, and 10.7 million long tons in 1980, 1990, and 2000 respectively. In short, although we believe our estimates of PRO use are reasonable in the light of current information, it is important to note that we have offsetting assumptions, i.e., if we are low on PRO in electric furnaces, we are probably also low on basic oxygen furnace use of scrap.

1/ Sacilor, the French steel company, has put into operation a new Kaldo plant with an initial capacity of 1.6 million tons per year. (Iron and Steel Engineer, January 1970, p. D43).

2/ Ibid., pp. D43 and D44.

Continuous Casting

The conversion of raw steel to the various types of more finished steel is done now primarily through a variety of rolling mills. These produce the basic primary shapes of the steel industry, i.e., plates, sheets, bars, structural shapes, pipes, tubes, wire rods, and rails. Other more complex forms are cast and forged. The basic steel shapes, which account for almost all steel production, start out as ingots and are then reduced to two basic forms by large primary rolling mills. These two forms are slabs for flat products and blooms for sectional products. Ingots must first solidify and then must be stripped from their molds, cropped and reheated in soaking pits to remove internal stress, and brought to rolling temperature. They then proceed to the primary mills to emerge as slabs or blooms. The largest production of plant scrap occurs in the cropping of ingots, slabs and blooms.

The continuous casting process avoids these stages. In its initial stages of development about 10 years ago, it was limited to a relatively narrow range of sizes and steel shapes (smaller sized slabs, blooms and billets) and a relatively narrow band of steel qualities. Its capacity in its early stages was in small- to moderate-tonnage plants, plants with capacities up to perhaps .5 million tons per year. Now it has been developed to much larger sizes and capacities in both slabs and blooms, and capacities have increased to well over 1 million tons per year. The process is being continually improved, and there is little doubt that in 15 years it will be a significant competitor of the rolling process.

The relevance of continuous casting to our problem is that the yield from raw steel to the basic finished forms is much higher in the continuous casting process. It has other operating (cost) advantages as well. Since the yield is significantly higher it entails less raw steel per ton of finished steel. It fol-follows from this that any projection of ingot production on the basis of the past relationship of ingots to rolled steel will overstate raw steel requirements since continuous casting will be a significant process

by 1980. In the view of many observers, the conventional ingot casting process requiring soaking pits and large primary mills will by the turn of the century be almost phased out.1/

As of 1968, 13 million tons of continuous casting capacity was utilized in the United States. By January 1970, 19 million tons of continuous casting capacity was operational in the United States.2/ Our forecast is that by 1980, 30 percent of all raw steel will be continuously cast; by 1990 and 2000, 75 and 85 percent of all raw steel will be continuously cast. Since less raw steel is required per ton of finished steel using continuous casting, less total metallics are required per ton of finished steel. This is further discussed in chapter III.

Iron Ore Technology

Direct Shipping Ore and Beneficiated Ore

The tonnage of iron ore which will be imported into the United States depends upon the Fe content of the ore, among other things. The trend in the United States as in all the major producing countries has been to increase the proportion of beneficiated ores charged into blast furnaces. Of the total of approximately 90 million long tons of iron ore shipped from U.S. mines in 1969, 9.7 million tons were direct-shipping ore with an average Fe content of 51.8 percent; 56.3 million tons were agglomerates, with 62.5 percent Fe content; and 24.6 million tons were concentrates, with 54.8 percent Fe content. The average Fe content of all usable ore in the United States in 1969 was 59 percent. Table 26

1/ "Continuous casting will make steel ingots obsolete, and combined with simple rolling operations will turn out large percentage of finished shapes," H.T. Reno & F. F.E. Brantley, "Iron," in Mineral Facts and Problems, Bureau of Mines Bulletin 650 (Washington, D.C.: Government Printing Office, 1970).
2/ Iron and Steel Engineer, January 1970, p. D37.

shows the trend in the proportion of beneficiated ore (agglomerates and concentrates) of total ore since 1965. As of 1970, 60 million tons of pellets were produced in the United States, about 70 percent of total usable iron ore production. Expansion of pellet capacity is continuing in Minnesota and Michigan. Canadian pellet production was 16 million tons in 1970, and current plans of the Iron Ore Company of Canada call for an expansion of 16 million tons of pellets by 1972.1/

Table 26. Beneficiated Ore Shipped from U.S. Iron Ore Mines, 1965-69

(In thousands of long tons)

Year	Beneficiated	Total	Percent beneficiated
1965.......	64.7	84.1	76.9
1966.......	70.5	90.0	78.2
1967.......	66.2	82.4	80.3
1968.......	72.8	81.9	88.8
1969.......	80.2	89.9	89.2

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1969, p. 576.

Beneficiation of Imported Ore

The Fe content of ores imported into the United States varies with the country of origin. Most Canadian ores used in the United States will be agglomerates (mostly pellets) made from low-grade ores and averaging about the same Fe content as Lake Superior pellets. Ores from South America (Venezuela, Chile, Peru, Brazil) and Africa (Liberia) have naturally high Fe content (60 to 68 percent). By 1980 it is probable that between 90 and 95 percent of all U.S. mined ore will be

1/ Ibid., p. D27.

beneficiated, and by 2000 probably 100 percent of U.S. ore will be agglomerated.1/

Most iron ore imported from other countries by the United States will also be agglomerated. However, the significant question for purposes of this study is how much of this foreign ore will be agglomerated before arriving in the United States, and the percentage of iron of these imported agglomerates -- since this of course directly determines the actual tonnage which U.S. ports will handle. For the next decade, that is to say to about 1980, it is very likely that agglomerates used in U.S. blast furnaces will not average above 65 to 75 percent Fe. One constraint on Fe content of the charge is the necessity of obtaining sufficient slag volume to eliminate sulfur in the coke, which is present even in the best quality coking coal. However, much experimentation is going on with higher metallized ores, and it is probable that some of the agglomerates charged into blast furnaces in the future may be as high as 85 to 95 percent Fe content, thus increasing the average Fe content of ores charged into the blast furnace.

The effect of higher Fe charges into blast furnaces is to reduce the coke rate and increase the iron output of the furnace.2/ We can therefore expect that in the decades beyond 1980, such practice will be increasingly common. The U.S. Bureau of Mines, for example, expects that by 2000 half the agglomerates used in the United States will be prereduced (i.e., metallized to about 95 percent), so that the average Fe content of agglomerates will be about 80 percent Fe. How much

1/ This is also the opinion of the U.S. Bureau of Mines. See U.S. Department of Interior, Preprint from the Bureau of Mines 1970 Minerals Yearbook, "Iron Ore," 1970, p. 50.
2/ Stelco of Canada, for example, used 91 percent metallized pellets for about 30 percent of the ore burden in a production-sized blast furnace in a test program. The coke rate decreased by 17 to 21 percent, slag volume decreased by 3 to 14 percent and hot metal productivity increased 16 to 23 percent. Iron and Steel Engineer, January 1971, p. 28.

prereduction will take place abroad is of course a basic uncertainty. The magnitude of the tonnage change, depending upon the Fe content, is of great significance in deepwater port planning. Table 27 gives tonnages of actual ore required per million tons of Fe at average Fe contents of 95 percent, 90 percent, 80 percent, 70 percent and 60 percent.

Table 27. Tonnage of Actual Ore Required Per Million Tons of Fe at Varying Percentages of Fe Content

Fe content (percent)	Ore tonnage (millions)	Index (60% Fe=100)
95.........	1.05	63.2
90.........	1.11	66.7
80.........	1.25	75.0
70.........	1.43	85.7
60.........	1.67	100.0

<u>Savings in Shipping Costs from Prereduction</u>

Whether such reduction in the tonnage of imports takes place because ore is prereduced in the ore-exporting countries depends upon the conjuncture of iron ore with cheap sources of coal and hydrocarbons in the ore-exporting country. Even if the cost of such fuels were equal or more expensive in the ore-exporting country, the savings in transportation costs would be an important pressure toward having prereduction take place in the exporting country.

For example, the U.S. Steel Corporation plant in Texas (Baytown) is based upon prereduction of iron ore in Venezuela by a fluidized bed process based upon Orinoco natural gas. The steel will be produced by an electric-arc steelmaking furnace, which will feed a continuous casting facility. This plant will receive briquets (92 percent Fe) produced in the metallizing plant in Puerto Ordaz, Venezuela, with an initial capacity of 1.5 million tons per year of briquets ranging

from 86 percent Fe (for blast furnace feed) and 92 percent for electric steelmaking.

In the case of U.S. Steel, the equivalent tonnage of ore imported from Venezuela to produce 1,350,000 tons of iron (1.5 million tons of briquets at 90 percent Fe) would be 2,250,000 tons of iron ore (60 percent Fe), a reduction of 750,000 tons per year, or a one-third reduction, for this one plant alone. If we use a figure of $1.64[1] per ton as the cost of shipment in a 65,000-ton carrier from Puerto Ordaz to Texas, this would result in a saving of $1,230,000 per year in shipping costs alone. Since Orinoco natural gas is cheaper than Texas gas, an additional economy is achieved. Some idea of the magnitude of savings in shipping costs from potential foreign sources of iron ore for U.S. steel companies per million tons of iron content is given in table 28.

It is not possible to accurately predict how much prereduction of iron ore will take place in the countries listed in table 28. Other than in Venezuela, Canada and Australia, deposits of coal and hydrocarbons in these countries at present are either too small or are not known. Table 29 shows the 1969 production of coal (all grades), natural gas and crude petroleum for all the potential iron ore exporting countries which can be considered as sources of iron ore for the United States. However, the energetic search for oil and gas which is now taking place in the West African countries, Australia and Brazil, as well as the presence of coal in these countries makes it likely that by 1990 most of the countries shown in table 28 will have some output of metallized ore.

To assume that no prereduction of iron ore will take place in the exporting countries would be to exaggerate the tonnage of imports. Venezuelan ore is already being prereduced both by the Government of Venezuela and by the U.S. Steel Corporation, and Australia will

1/ This is the U.N. "theoretical" shipping cost of iron ore in 1975. Source is given in table 28.

Table 28. Savings in Shipping Costs from Prereduction per Million Tons of Iron Content, by Country of Export

Exporting country	Shipping cost: Per ton of ore	Shipping cost: Of 63% Fe ore	Shipping cost: Of 90% Fe ore	Savings in shipping cost
	($/ton)	(mil. of dol.)		
Canada (east).....	.92	1.587	1.022	.565
Brazil............	2.68	4.254	2.978	1.276
Chile.............	3.53	5.603	3.922	1.681
Peru..............	2.75	4.365	3.056	1.309
Venezuela.........	1.64	2.603	1.822	.781
Gabon.............	3.06	4.857	3.400	1.457
Liberia...........	2.48	3.937	2.756	1.181
Sierre Leone......	2.37	3.762	2.633	1.129
Australia.........	7.52	11.936	8.355	3.581
Sweden/Norway.....	2.37	3.762	2.633	1.129

Note: The costs are based upon 65,000 d.w.t. carriers to the ports of Mobile and Baltimore. The figures would therefore be approximately the same for any gulf coast or Middle Atlantic ports. The savings would be more if smaller vessels were used, and less if larger vessels were used, because of differences in unit shipping costs.

Source: United Nations, The World Market for Iron Ore (ST/ECE/Steel/24), 1968, table 112, p. 190.

Table 29. Production of Coal and Hydrocarbon of Potential Iron Ore Exporting Countries, 1969

Country	Coal	Crude petroleum	Natural gas
	(mil. ton)	(mil. bbls.)	(bil. cu. ft.)
Canada..........	10.7	407.5	1,985.3
Brazil..........	2.7	64.0	8.0
Chile...........	1.9	13.4	33.5
Peru............	.2	26.3	17.5
Venezuela.......	a/	1,311.8	314.1
Gabon...........	--	36.4	.9
Liberia.........	--	--	--
Sierre Leone....	--	--	--
Australia.......	76.5	15.8	9.[illegible]
Sweden/Norway...	a/	--	--

a/ Less than 100,000 tons.

have a metallized ore, "Hi Met," in production, as will Brazil, in 2 years. We are almost certain that U.S. imports of iron ore will have increasing iron content in the future because of the significant transportation savings accruing to the importers, the additional value added to the iron ore by the exporting country, and the existence now of technology capable of direct reduction. The uncertainty is how soon and how extensive this development will be, particularly in the underdeveloped countries which will require foreign capital on a large scale to finance such development. For Venezuela, Canada and Australia, we do not think that capital requirements will prove difficult. As a consequence we have calculated iron ore imports on two bases: the tonnage of standard ore at 63 percent Fe content, and the expected actual tonnage with higher iron content. These tables are given in chapter I. For 1980, the difference between standard iron content of 63 percent and the expected iron content of 66.8 percent results in a difference of 2.6 million tons. We forecast this difference by 2000 to be 13.3 million tons. Our expectation of the average Fe content by importing country is shown in table 7.

III. IRON ORE REQUIREMENTS, PRODUCTION AND IMPORTS, 1980-2000

Methodology

Projection Models

The end result of the analysis must be a forecast of the actual tonnage of iron ores and agglomerates which will enter U.S. ports in 1980-2000. There are two possible classes of models to choose from: direct trend models and indirect models.

Direct Trend Models

We can fit the time series of iron ore imports for each deepwater port of the United States and can project these relationships of best fit to 1980 and 2000. If we were completely ignorant of the changes occurring in iron and steel technology and of the changing economic forces in the United States as they shape industrial location patterns, this is the procedure we would be forced to use. Alternatively, if we were convinced that the technology and locational shifts of the U.S. steel industry were moving at glacial pace, we would also choose this procedure.

Such time trend models are acceptable for only very short period forecasting, or under either of the above conditions. If for example we had projected on the basis of time series data on iron ore imports from 1890-1920 to the period 1930 and 1940, we would not be so far off. However, if we had projected iron ore imports on the data 1900-40 to the period 1960 and 1970,

we would have been very far off the actual results. For during the period from 1945 on the United States was undergoing a rapid and substantial change from a net exporter of iron ore to a very large net importer of iron ore. In 1945 the United States imported 1.2 million gross tons of iron ore; by 1966 this had increased to 46.3 million tons; it has declined since then, so that by 1970 the imports were approximately 40.3 million tons. Such a rate of growth obviously cannot be projected far into the future. If we use some S-shaped curve, we are somewhat better off, but we are still guessing rather blindly and allowing mechanical procedures to cover up lack of knowledge.

Indirect Models

We can project iron ore imports on the basis of more complex indirect models linking iron ore imports to intermediary variables such as steel production, GNP, usage of steel per dollar of GNP, and so forth. Though we cannot avoid time trend analysis, the indirect models permit the explicit choice of values of economic and technological variables, which on the basis of present knowledge will bracket the range within which the actual results are likely to lie.

Model Used to Estimate Tonnage of Iron Ore Imports

The model used to estimate the tonnage of iron ore imports1/ by U.S. ports for 1980-2000 is a two-part model. The first part estimates the total U.S. imports of iron ore for the target years. The second part distributes these imports by deepwater ports and by countries of origin.

The National Model

The demand for iron ore is a demand derived from the demand for finished steel and iron products; we

1/ Iron ore refers to iron ore, agglomerates, and prereduced ores such as highly metallized nodules, briquets, pellets, etc.

refer to the latter as "foundry products." The demand for the finished products derives in turn from the demand for goods and services made of steel and iron or requiring these finished iron and steel products. A starting point therefore is the estimation of the demand for goods made of iron and steel. There are two ways of estimating this: one is to estimate the iron and steel demand industry by industry (or in a more sophisticated fashion, by using input-output tables) for 1980 and 2000. Obviously no input-output tables are available for 1980 or 2000. Estimating demand industry by industry for a series of major iron and steel consuming industries is the method chosen by the Bureau of Mines. But such a method requires knowledge about the long-run future status of these industries, which no one has.

Another method is to proceed on a more aggregative basis by: (1) estimating the gross level of economic activity (GNP) in the United States for 1980 and 2000, and (2) estimating the use of steel per unit of gross economic activity.

A measure of (2) is "Apparent Consumption of Finished Steel" (abbreviated as ACFS) per dollar of GNP. It is "apparent" because there is no reliable measurement of finished steel inventory in the United States. The ratio of ACFS to GNP is a very aggregative measure of the steel content per unit of real GNP. One can draw some inferences as to why it has behaved the way it has over time, and our explanation may provide a basis for estimating its future behavior.

Basic Relationships of the National Model

The basic relationships of the national model may be summarized as follows:

1. Iron ore requirements equal the iron ore necessary for domestic primary iron production.

2. Iron ore imports are iron ore requirements minus iron ore production. These two relations are definitions. The unit used is standard iron ore of

63 percent Fe. This unit is transformed into actual tonnage of imports on the basis of the estimated actual Fe content of imported iron ore. The implicit invariant measure is the weight of iron units. It should be noted that U.S. iron ore exports have not been included in requirements, so that imports are gross iron ore imports, which are the relevant measure of the import load on U.S. ports.1/

3. Iron ore requirements are a function of domestic primary iron production (hot metal, pig iron and PRO), and the state of primary iron technology.

4. Iron ore production is a function of primary iron production and the state of beneficiation and iron ore reduction technology.

5. Primary iron production is a function of raw steel and foundry iron production and the corresponding technologies.

6. Raw steel production is a function of finished steel production and the state of finished steel technology.

7. Finished steel production equals apparent steel consumption plus exports of finished steel minus imports of finished steel.

8. Apparent finished steel consumption is a function of the level of real GNP and the composition of GNP.

9. Imports of finished steel are a function of the prices of U.S. finished steel and imported steel at points of consumption, and U.S. Government import policy.

1/ In fact the United States does export some iron ore amounting to about 5 to 6 million tons, about two-thirds of which are Far Western ores leaving from the Pacific coast. The Pacific coast is not expected (in the forecast period) to have significant imports of iron ore. The other one-third is exports to Canada on an exchange basis. This portion has been declining in recent years and is expected to continue to decline.

10. Real GNP is a function of time.

It should be understood that these relations refer to the period 1980-2000. Though we have not stated so above, items 6 and 7 have analogous relations for iron foundry products. The "state of technology" for each phase of the steel industry, i.e., from iron ore mining and beneficiation through continuous casting, has already been discussed in chapter II. The major assumptions on the proportion of steel furnace types, the composition of metallic inputs by furnace type, the rate of expansion of PRO, and the proportion of continuous casting of total raw steel have been set forth, as have the reasons therefore. In this section, the "state of technology" appears only in the form of appropriate yield factors, i.e., iron ore used per ton of primary iron produced, raw steel per ton of cast slab, bloom or billet and so forth. The major problem for the national model is the forecast of finished steel and iron consumption and the forecast of net steel imports. Given these forecasts, metallic and iron ore requirements depend upon the assumptions already made for the state of technology over the period 1980-2000 and for the yield factors appropriate to these technologies. Given the national iron ore requirements we must forecast the domestic production of iron ore in order to determine imports. In chapter IV we treat the submodel which translates total iron ore imports into U.S. port loads.

The Rate of Growth of Real GNP

The GNP growth assumptions employed in the deepwater port study are set forth in annex A-1 of the study. These assumptions are that the annual average rate of real growth will be 4.3 percent from 1968 to 1980, 3.8 percent from 1980 to 1990, and 4.2 percent from 1990 to 2000. The average over the entire period is 4.1 percent.

The Composition of Output

For a given level of GNP it is possible to have varying levels of steel consumption. Since World War II

the consumption of steel (in tons) per dollar of GNP (in constant dollars) has exhibited a declining trend. In part this is due to a changing composition of GNP; those goods and services requiring relatively little steel, directly and indirectly, have become a larger proportion of GNP. The second factor accounting for this trend is that within that group of goods and services which use relatively large amounts of steel, some have substituted other products (aluminum, plastics, paper) for steel. The third factor is the use (in tons) of less steel due to the increasing quality of steel in terms of strength, resistance to corrosion, etc. The fourth factor is the improvements in the processes of machining and fabricating steels so that the yield of the end product is greater per ton of finished steel input.

Of these four factors which reduce the use of steel per dollar of GNP, the first is doubtlessly the most important. As table 30 shows, the goods-producing industries plus transportation and utilities (classified under services) have shown almost no increase in employment from 1947 to 1969 (+5 percent) whereas the low steel-using industries have increased by 81 percent. The projection for 1980 shows a similar picture. The proportion of GNP of the low steel-using service industries has greatly increased and will continue to do so.

The second factor -- materials substitution -- is relatively minor compared to the changing composition of GNP. Doubtless some materials such as concrete, plastics, aluminum, glass and so forth have captured some markets formerly held by steel. But the shift has not all been in one direction. A study by the United Nations[1/] estimates that not more than 5 percent of the iron and steel products of an industrialized country are subject to competition from other industrial materials. The other factors (i.e., the use of alloy steels and the greater efficiency in the materials fabrication of products made from iron and steel) are doubtlessly

1/ United Nations, Economic Commission for Europe, Aspects of Competition Between Steel and Other Materials (66 II E 1).

Table 30. Wage and Salary Employment in Goods-Producing and Service-Producing Industries, 1947 and 1969 Actual, and 1980 Projected

(In millions)

Classification and industry	Actual 1947	Actual 1969	Projected 1980	Percentage change 1947-69	Percentage change 1969-80
Goods-producing industries.......	26.4	27.8	30.0	5.3	8.1
Mining............	1.0	0.6	0.6	-34.2	-12.4
Contract construction.......	2.0	3.4	4.6	72.0	34.9
Manufacturing (durable and nondurable goods)..........	15.5	20.1	21.9	29.4	9.0
Agriculture......	7.9	3.6	2.9	-54.3	-18.8
Service-producing industries.......	25.4	46.0	59.5	81.0	29.4
Transportation and public utilities........	4.2	4.4	4.7	6.8	6.5
Wholesale and retail trade......	9.0	14.6	17.6	63.5	20.4
Finance, insurance, and real estate..........	1.8	3.6	4.3	102.9	19.7
General services.	5.1	11.1	16.1	119.8	44.9
Federal government............	1.9	2.8	3.0	45.5	9.0
State and local government......	3.6	9.5	13.8	163.1	46.4
All industries....	51.8	73.7	89.5	42.4	21.4

Note: The table shows employment; however, GNP by sector is approximately proportional to employment by sector.

Source: U.S. Department of Labor, Bureau of Labor Statistics, The U.S. Economy in 1980, Bulletin 1673, August 1970, Table A-22, pp. 53-56. Figures are rounded and may not add to totals.

very small factors in reducing the use of iron and steel per dollar of GNP. Alloy steels may actually result in more steel being used rather than less since they may displace other nonsteel materials. We believe that finished iron and steel use per unit of real GNP will decline in the future, but at a lower rate than in the past. Just how much this decline will be is discussed in a subsequent section.

Finished Steel Consumption Vs. Production

No annual data are available which directly measure the consumption of finished steel products. A consumption series may be devised from the following equality: Consumption = production + imports - (exports + inventory change). Because we do not have an annual series of steel products inventory, we have only an approximation, i.e., apparent steel consumption. As a consequence the relationship between finished steel consumption, GNP, and time will be subject to disturbances, part of which are due to inventory fluctuation. Over the 24 years from 1947 to 1970, we may expect these inventory fluctuations to average out, so that little if any bias from this source should occur.

The question we face is whether to use production of finished steel products or consumption of finished steel products as the dependent variable in an equation in which the independent variables are GNP and time. If the net balance of foreign trade in steel were zero or stable over time, there would be little to choose from since we do not in any case have an annual inventory series. However, during the period 1947-70 there has been a remarkably large shift in the balance of U.S. foreign trade in steel. From 1947 to 1958 the balance was favorable, though more favorable in the early years when European and Japanese industry was completely disrupted. From 1958 through 1970 the balance shifted adversely for the United States, becoming progressively more so. In 1968 imports of steel products reached a peak of 18.5 million tons against U.S. exports of only 2.5 million tons. This contrasts with 1947 when U.S. exports of steel products were 6.5 million tons and imports were only 0.03 million tons. Preliminary data for 1970 indicate a sharp drop in imports and an

increase in exports, with a net import of steel of about 6.4 million tons, the lowest since 1965 (table 31).

It is clear that such a shift in the terms of steel trade during 1947-70 would make steel production a poor indicator of steel consumption. It would bias steel consumption upward in the early years, and bias it downward in the later years. Thus if the two sets of ratios, steel production/GNP and steel consumption/ GNP, were fitted for their trend over time (1947-70), the time trend of the former would have a steeper negative slope than the latter. The forces which we mentioned tending to lower steel consumption (which are also reflected in the production series) would be augmented by the adverse trend in the steel foreign trade balance. Moreover, we should expect that the statistical relationship between steel consumption and GNP would contain less unexplained variance than production and GNP when there are substantial and unstable foreign trade balances in steel.

This is in fact the case; the multiple correlations using consumption as the dependent variable are superior to those in which production is the dependent variable when the same independent variables and function type are used. One further advantage in using consumption is that we can explicitly vary the estimate of the net balance in steel trade for 1980 on the basis of qualitative arguments. This is necessary since it is doubtful that a permanent pattern of such trade for the United States has yet been established. The reasons for this position are developed below. The reason for using finished steel rather than ingot steel or raw steel as the variable is that the amount of raw steel produced depends upon the type of finished steel produced (both the physical form and chemical composition) and upon the amount of raw steel which will be continuously cast. The former is fairly stable so that yield factors are fairly stable; the latter as we know will change greatly.

Arguments on the Net Balance of Foreign Trade in Steel

The net balance of foreign trade in steel for the United States in 1980 will not be as unfavorable

Table 31. U.S. Exports and Imports of Finished Steel, 1947-70

(In millions of net tons)

Year	Exports	Imports	Net balance
1947..................	6.47	.03	+ 6.44
1948..................	4.28	.15	+ 4.13
1949..................	4.65	.30	+ 4.35
1950..................	2.86	1.80	+ 1.78
1951..................	3.27	2.28	+ .99
1952..................	4.15	1.23	+ 2.92
1953..................	3.07	1.74	+ 1.33
1954..................	2.80	.88	+ 1.92
1955..................	4.08	1.08	+ 3.00
1956..................	4.77	1.48	+ 3.30
1957..................	5.95	1.30	+ 4.65
1958..................	3.24	1.83	+ 1.41
1959..................	1.98	4.63	- 2.65
1960..................	3.22	3.58	- .36
1961..................	2.23	3.32	- 1.09
1962..................	2.27	4.31	- 2.04
1963..................	2.56	5.66	- 3.10
1964..................	3.74	6.71	- 2.97
1965..................	2.84	10.75	- 7.91
1966..................	2.03	11.17	- 9.14
1967..................	1.97	11.92	- 9.95
1968..................	2.50	18.46	-15.96
1969..................	5.60	14.62	- 9.02
1970..................	7.45 a/	13.89 a/	- 6.44

a/ Preliminary for 1970.

Source: U.S. Department of Commerce.

as it is now. We expect that it will decline as a percentage of total U.S. steel consumption from the 1965-70 levels. The reasons for this are as follows:

1. The wage rate gap between the United States and other steel-producing countries which account for the major source of U.S. imports of steel (namely Japan and Western Europe) has been narrowing and will probably continue to narrow. As table 32 shows, Western Europe and Japan have had much more rapid increases in steel wage rates than U.S. steelworkers. The latter have increased at an average annual rate of 3.24 percent over the 10-year period from 1959 to 1968. The lowest average is Luxembourg with 8 percent, while Japan's has been 13.5 percent and the Netherlands' even greater at 15.7 percent. It is very likely that by 1980 the increase in the U.S. steel industry will probably not exceed the historical rate, while the wage rates of steelworkers of the other countries will move up more rapidly.

We have computed the 1980 wage rates on the assumption that Belgium, Luxembourg and Japan will continue to increase the steel wage rate at their historical average, while the Netherlands, with the highest Western European rate, will increase at the average of West Germany, Belgium and Luxembourg. West Germany will increase at the average of its other three Western European neighbors -- its strongest steel competitiors. The absolute gap between U.S. and foreign earnings will narrow. The Japanese gap does not narrow much ($3.51 in 1980 as against $3.69 in 1968) as shown in table 32. However, it is very likely that by 1990 the wage gap between the U.S. steelworker and his counterparts in Western Europe and Japan will be further narrowed, and we conjecture that the wage gap will be no more than 10 to 15 percent. The unit labor cost differentials as of 1968 are lower than the wage differential, for in terms of output per wage employee the United States was higher than its competitors.[1]

1/ Raw steel production per employee per year for Japan in 1968 was 170 net tons, while for the United States it was 238 net tons. The annual employment cost per Japanese steelworker was $3,187 compared to $10,626

Table 32. Average Hourly Earnings of Steelworkers, 1959-68, and Projected 1980

Country	Actual 1959	Actual 1963	Percent change, 1959-63	Actual 1968	Percent change, 1963-68	Percent change, 1959-68	Projected[a/] 1980
	(dol.)			(dol.)			(dol.)
U.S.	3.80	4.25	11.8	5.03	18.4	32.4	6.66
West Germany	1.12	1.59	42.0	2.09	31.5	86.6	4.52
Belgium	1.13	1.45	28.3	2.27	56.6	100.9	4.56
Luxembourg	1.31	1.62	23.7	2.36	45.7	80.1	4.26
Netherlands	.95	1.58	66.3	2.54	60.8	156.8	4.81
Japan	.57	.80	40.4	1.34	67.5	135.1	3.15

a/ U.S. at average rate 1959-68 = 32.4 percent. West Germany at average rate 1959-68 of Belgium, Luxembourg, and Netherlands = 116.3 percent. Belgium at average rate 1959-68 = 100.4 percent. Luxembourg at average rate 1959-68 = 80.2 percent. Netherlands at average rate of Belgium, Luxembourg, and West Germany 1959-68 = 89.2 percent.

2. The U.S. steel industry by 1980 will probably be at least as technically advanced as the best foreign producers. By 1980 U.S. steel furnaces will have an age composition and average furnace size comparing favorably with the Japanese industry.1/ The United States will have proportionately as much if not more continuous casting2/ as any other country, and its finishing mills will be equal or superior to any. U.S. blast furnaces will not on the average be as large as Japan's, but will be much improved over their current status, and in direct reduction and electric furnace technology the United States is likely to be in the lead. This should help to offset any Japanese advantage in hot metal, which in any case is bound to be small.

3. The advantages of relatively cheap raw materials (e.g., coking coal, other fuels and energy, scrap, and to some extent iron ore) which the United States now has will continue in the future.

The consequences of these three factors are likely to narrow the cost gap between U.S. producers of steel compared to those of Japan and Western Europe in

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for the United States -- a ratio of 3.33 compared to the hourly ratio of wages of 3.75. These data are derived from "Steel Imports a National Concern," American Iron and Steel Institute, July 1970, Tables 17 and 13.

1/ The great growth and modernization of the Japanese steel industry and also that of West Germany occurred in the last half of the 1950's and in the decade of the 1960's. That of the United States started in the last part of the 1960's and will continue in the decade of the 1970's. By 1980 the U.S. steel industry will have been largely rebuilt.

2/ In 1968 the United States had 13 million tons annual capacity in continuous casting. As of August 1969 the entire world capacity was 38 million tons, of which the United States had over 40 percent. As of August 1970 there were 33 continuous casting facilities in Japan with a capacity of 7.7 million tons. As of 1975 Japan expects to have about 50 continuous casting plants with 16 million tons. We expect U.S. capacity as of 1975 to be over 35 million tons. See Blast Furnace & Steel Plant, November 1970.

1980, and probably even more so after 1980 as the wage gap narrows.

4. The growth of underdeveloped countries will increase export markets in absolute terms. Even though many of these countries will become steel producers and will utilize an increased proportion of domestic steel, their demand will increase even more rapidly and particularly in the more sophisticated steel products in which these countries will have only limited capacity. There should be therefore increased opportunity for U.S. exports of finished steel.

5. The inability of the United States to export large quantities of steel results not only from the higher cost of U.S. steel products but also from the restrictions and high tariffs of both underdeveloped and developed countries. We do not think this situation will prevail in the future without offsetting U.S. action. The present decoupling of the U.S. dollar from gold and devaluation relative to gold and other currencies is the first step in this direction.

6. U.S. steel producers will take countersteps to halt the increase in imports which in 1968 reached a high point of 15 percent of U.S. domestic production. This action will take many forms ranging from political pressure to more aggressive marketing abroad, extensive rebuilding of the U.S. steel industry, and increased expenditures on research and development. The large increase in U.S. exports in 1969 and 1970 (table 31) may be more typical of the future than the record of 1960-68. Table 33 shows the percentage of the adverse net import balance of apparent U.S. finished steel consumption. In view of the recent foreign trade and international monetary actions of the U.S. Government, we incline to the view that the downturn in the percentage of imports is not merely transitory. We do not think that the 1968 peak (14.8 percent) will often be repeated in the future.

As a consequence of the above considerations we believe that in the future the United States will show a smaller net balance of imports than the 1960-70 average of 6.9 percent. For 1970-80 we think 5.0 percent is most likely. For 1990 and 2000 we have chosen

Table 33. Net Imports as a Percentage of Apparent Finished Steel Consumption, 1960-70

Year	Apparent finished steel consumption	Net import balance	Net balance as percent of apparent consumption
	--- mil. net tons ---		
1960.......	71.5	.3	.4
1961.......	67.3	1.09	1.6
1962.......	72.6	2.04	2.8
1963.......	78.8	3.10	3.9
1964.......	87.9	2.97	3.4
1965.......	100.6	7.91	7.9
1966.......	99.1	9.14	9.2
1967.......	93.9	9.95	10.6
1968.......	107.9	15.96	14.8
1969.......	102.9	9.02	8.8
1970.......	96.7	6.44	6.7
1960-70 weighted average...			6.9

the same net import balance. We cannot at this point see convincing evidence to change this percentage.

Estimating Apparent Consumption of Finished Steel, 1980-2000

Rates of Growth

The rate of growth in apparent finished steel consumption from 1947 to 1970 approximates an annual compound rate of 2.15 percent. If we use the average of the past 5 years (1966-70) as a trend value for 1970 rather than the 1970 actual value, the rate is slightly higher (about 2.2 percent). Real GNP has been growing at about 3.5 percent per year, while steel consumption has been declining relative to GNP (tables 34 and 35). A simple way of estimating apparent consumption of finished steel (ACFS) is therefore to project the historical growth rate. Even though GNP will continue to grow at a greater rate than steel consumption, this is not open to serious objection since it is clear that the decline of steel use per billion dollars of real GNP will undoubtedly continue at least through 1980, as the proportion of low steel-using industries will continue to constitute a higher proportion of total GNP.

Statistical Methods

Numerous purely statistical methods were tried, all involving multiple correlation analysis and linear forms, with ACFS as the dependent variable and GNP and time as independent variables. The following forms were examined:

$$\text{ACFS} = K + X_1 \text{ GNP} + X_2 \text{ Time } (1947=1) \qquad (1)$$

$$\Delta\text{ACFS} = K + X_1 \, \Delta\text{GNP} + X_2 \text{ Time } (1947=1) \qquad (2)$$

$$\text{ACFS/GNP} = K + X_1 \text{ Time } (1947=1) \qquad (3)$$

All of these showed negative coefficients for time (i.e., less steel per dollar of GNP) each succeeding year. The first form implies a constant tonnage reduction of ACFS per year independent of the value of

Table 34. Gross National Product, Steel ingot Production and Net Shipments of Steel Products, 1947-70

Year	GNP	Steel ingot production	Net shipments of steel products
	(bil. 1958$)	(mil. of net tons)	
1947...........	309.9	84.9	63.1
1948...........	323.7	88.6	66.0
1949...........	324.1	78.0	58.1
1950...........	355.3	96.9	72.2
1951...........	383.4	105.2	78.9
1952...........	395.1	93.2	68.0
1953...........	412.8	111.6	80.2
1954...........	407.0	88.3	63.2
1955...........	438.0	117.0	84.7
1956...........	446.1	115.2	83.3
1957...........	452.5	112.7	79.9
1958...........	447.3	85.3	59.9
1959...........	475.9	93.5	69.4
1960...........	487.8	99.3	71.2
1961...........	497.3	98.0	66.1
1962...........	530.0	98.3	70.6
1963...........	551.0	109.3	75.6
1964...........	580.0	127.1	85.0
1965...........	617.8	131.5	92.7
1966...........	658.1	134.1	90.0
1967...........	675.2	127.2	83.9
1968...........	707.2	131.5	91.9
1969...........	727.1	141.3	93.9
1970...........	724.1	131.3[a]	90.3[a]

a/ Preliminary figures.
Source: U.S. Department of Commerce; and American Iron and Steel Institute, Annual Statistical Report.

Table 35. Ratios of Apparent Consumption of Finished Steel Products, Ingot Production and GNP, 1947-70

Year	Ratio of apparent consumption to GNP	Apparent steel consumption	Two-year moving average	Ratio of ingot production to GNP
		(mil. tons)		
1947.....	.1846	57.2	.1884	.2740
1948.....	.1922	62.2	.1796	.2737
1949.....	.1664	54.1	.1828	.2407
1950.....	.1987	70.6	.2011	.2727
1951.....	.2034	78.0	.1842	.2744
1952.....	.1650	65.2	.1781	.2359
1953.....	.1911	78.9	.1706	.2704
1954.....	.1501	61.1	.1682	.2170
1955.....	.1863	81.6	.1831	.2671
1956.....	.1798	80.2	.1736	.2582
1957.....	.1673	75.7	.1494	.2491
1958.....	.1315	58.8	.1415	.1907
1959.....	.1515	72.1	.1491	.1965
1960.....	.1466	71.5	.1410	.2036
1961.....	.1353	67.3	.1362	.1971
1962.....	.1370	72.6	.1400	.1855
1963.....	.1430	78.8	.1473	.1984
1964.....	.1516	87.9	.1572	.2191
1965.....	.1628	100.6	.1567	.2129
1966.....	.1506	99.1	.1449	.2038
1967.....	.1391	93.9	.1459	.1884
1968.....	.1526	107.9	.1471	.1859
1969.....	.1415	102.9	.1376	.1943
1970.....	.1336	96.7 a/	--	.1813

Note: Apparent consumption of steel products is net shipments of steel products plus net balance when net balance is negative, and less net balance when it is positive. Ratio is millions of tons of steel per billion dollars of GNP.

a/ Preliminary figure.

GNP. Though this equation yielded acceptable statistical measures of fit and significance, the projections for 1980 implied a value of almost double that of 1970 when GNP was projected to grow at a 3.5 percent rate. This is so contrary to all that we know about the economy and the markets for steel that this form was rejected.

Form (2) says that a change in ΔACFS (first differences in steel consumption, or the change from year 1 to year 2) is dependent on the change in GNP and a time trend. This form is more logical,1/ but it yielded what we considered to be an extremely low value for 1980 at a GNP growth rate of 4.0 percent per year. It implied an increase of only 16 million net tons for 1980 from the actual 1970 value, which is less than a 2 percent per year growth rate of ACFS. The statistical results of this equation (i.e., R^2 and beta values) are acceptable.

Form (3) is a linear fit of the ratio ACFS/GNP as a function of time. The statistical results are inferior to form (2). This equation yields virtually no growth in ACFS when applied to the 1980 GNP values computed at 4.0 percent per year growth from 1970. The reason for this is that the decline in ACFS/GNP is not linear, though from 1947 to 1961 (as figure 4 shows) such a trend appears to be a reasonable approximation. From 1961 to 1970 the curve (figure 4) has obviously a different trend and a much lower rate of decline than from 1961 to 1970.2/ In short, the entire pattern from 1947 to 1970 is nonlinear.

It is clear that the ratio ACFS/GNP cannot decline linearly over time since it would eventually reach

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1/ By "logical" we mean the economics, not the mathematics. A large part of steel demand derives from investment and replacement; we would therefore expect that the change in GNP which is sensitive to changes in investment would be very highly correlated with the change in steel consumption.

2/ It is likely that the Korean and Vietnam wars account for some of the increase in the ACFS/GNP values in the early 1950's and 1964-68.

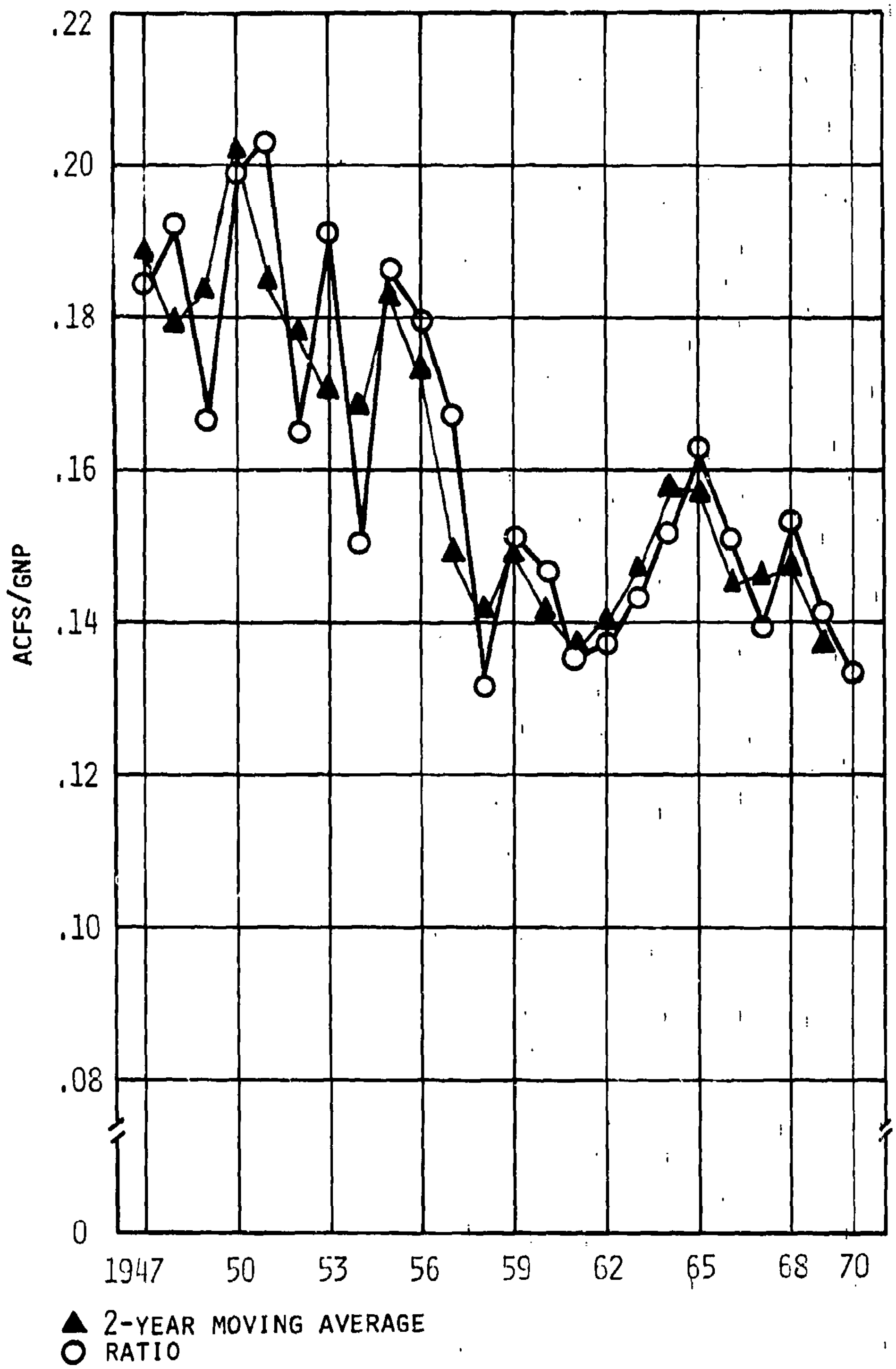

FIGURE 4. RATIO OF APPARENT CONSUMPTION OF FINISHED STEEL AND GNP, 1947-70

a zero value. An economy such as that of the United States must consume some amount of steel. Thus, the ratio must approach some asymptotic positive value. Although fitting such a nonlinear time trend on the basis of the past data is apparently an "objective" procedure, it is not completely so since much depends upon the functional form chosen. A further difficulty is that one must project as well the trend values of GNP for 1980, 1990, and 2000, since the ratio by itself will not yield a value for finished steel consumption. Thus, if we wish to obtain forecasts for steel consumption by using a nonlinear trend of ACFS/GNP, we require two forecasts, i.e., the ratio and the value of GNP. But these values are not independent, thus introducing additional statistical error. It seems to us preferable to forecast the consumption of steel directly.

Table 36 shows the values of finished steel consumption projected at three rates of growth: 2.00 percent, 2.25 percent, and 2.50 percent. As a comparison, finished steel consumption is calculated on the basis of three rates of decline in the ACFS/GNP ratio (1.00 percent, 1.25 percent and 1.50 percent per year) and three rates of growth in real GNP (3.00 percent, 3.5 percent, and 4 percent per year). Thirty-six possible projections of steel consumption, 12 for each of the years 1980, 1990, and 2000, are computed.

Our judgment is that the values derived from a 2.25 percent rate of growth in apparent finished steel consumption are most likely. We have used these values as the basis of the computations for iron ore requirements. It is interesting to note that they are very close to the values derived from assuming that GNP will increase at 3.5 percent per year and that ACFS/GNP will decline by 1.25 percent per year. They are also close to the values assuming a 4 percent per year growth in GNP with a 1.50 percent decline in the ratio.

Forecast of Foundry Consumption

Iron foundries produce two major kinds of iron castings: grey iron, which is over 90 percent of total iron castings, and malleable iron. The total tonnage

Table 36. Illustrative Projections of Finished Steel Consumption Calculated Under Varying Assumptions, 1980, 1990 and 2000
(Index: 1970=100[a/])

Assumptions	Finished steel consumption 1980	1990	2000
Growth rates of ACFS (pct. per year)			
2.00	121.9	148.6	181.1
2.25	124.9	156.1	194.9
2.50	128.0	163.9	209.8
Rates of decline in ACFS/GNP ratio (pct. per year)			
GNP growth at +3 pct. per year:			
-1.50	115.4	133.7	154.6
-1.25	118.2	140.3	166.6
-1.00	121.2	147.5	179.4
GNP growth at +3.5 pct. per year:			
-1.50	121.2	140.6	178.8
-1.25	124.2	154.6	192.6
-1.00	127.3	155.2	207.5
GNP growth at +4.0 pct. per year:			
-1.50	127.0	162.1	206.6
-1.25	130.1	170.2	222.6
-1.00	133.4	178.9	239.7

a/ 1970 value is average of 1965-70.

of iron castings has been declining per dollar of real GNP, but at a sharper rate than steel. This decline is primarily due to the same reasons as the decline in the consumption of steel relative to the level of GNP; i.e., industries using iron and steel are a declining share of total production of goods and services in the U.S. economy. Some loss of iron casting business has also occurred because of substitute materials. As with steel, we use the same method of forecasting the consumption of iron foundry products, that is, forecasting a simple growth rate on the basis of the historical trend of 1.1 percent per year. Imports and exports are relatively minor for these products, and we have ignored them.1/ Table 37 shows the shipments of iron castings which we take as equivalent to consumption,2/ the level of GNP, the ratio CIFP/GNP, and a 2-year moving average of this ratio (CIFP = consumption of iron foundry products).

As table 37 shows, the decline of the ratio from 1964 to 1970 has been 17 percent, or an average decline of 2.4 percent per year. The 2-year moving average has declined 18 percent, or an average decline per year of 2.6 percent. We see no reason for this rate to change significantly over the coming decades. The iron castings industry, even more than finished steel, serves a group of industries whose share in GNP is declining more rapidly than steel. Even iron use for engine blocks for automobiles, an important iron foundry product, has declined with the increasing proportion of smaller cars (and smaller engines). Further, engine blocks are subject to more intense substitute competition than steel. However, since GNP will grow more rapidly than the CIFP/GNP ratio declines, a small growth in foundry consumption is reasonable. The tonnage of iron foundry consumption on the basis of 1.1 percent growth per year and the implied ratio when GNP grows at 4 percent per year is shown in table 38.

1/ It is also difficult to distinguish iron foundry from steel castings in the export and import figures.
2/ Very little inventory is held of iron castings since most production is cast to order, so that shipments should be very close to consumption.

Table 37. Iron Foundry Products Consumption, and the Ratio of Consumption to Real GNP, 1964-70

(In millions of net tons; GNP in billions of 1958 dol.)

Year	Grey iron	Malleable	Total[a/]	GNP	CIFP[b/] ÷ GNP	Two-year moving average ÷ CIFP/GNP
1964...	14.3	1.0	15.3	580.0	.2641	
						.2668
1965...	15.7	1.1	16.8	617.8	.2725	
						.2643
1966...	15.7	1.1	16.8	658.1	.2560	
						.2418
1967...	14.3	1.0	15.4	675.2	.2275	
						.2282
1968...	15.1	1.1	16.2	707.2	.2288	
						.2319
1969...	15.9	1.1	17.1	727.1	.2350	
						.2198
1970...	14.0	.9	14.8	724.1	.2045	

a/ Figures will not add exactly due to rounding of original data, which were given in thousands of tons. Hence ratios calculated on original data are slightly different than those shown.
b/ The unit is in 100,000 tons per $ billion GNP (1958 dollars); i.e., figures should be read as 26,410 tons (1964), 20,450 tons (1970).

Table 38. Forecasts of Iron Foundry Consumption and CIFP/GNP Implied Ratio at GNP Growth Rate of Four Percent

Consumption and CIFP/ GNP ratio	1970	1980	1990	2000
CIPF/GNP implied ratio...	.2198	.1559	.1185	.0899
Consumption (million net tons)..................	14.8	16.7	18.8	22.1

As table 38 shows, the implied ratio declines by approximately 60 percent in 30 years, a somewhat lower rate than in the past. It should be noted that even significant errors in the forecasts will have only small effects on the total requirements for iron ore since iron foundries use mostly scrap compared to primary iron in their metallic charge.

The Calculation of Metallic Inputs

The key coefficients or yield factors on which the transformation of finished steel production into total metallics and total metallics into primary iron and scrap depends are:

1. The yield by furnace type.

2. The yield of finished steel from raw steel when conventional ingot casting is used and when continuous casting is used. All of the steel furnaces will have some proportion of their steel conventionally cast.

3. The inputs of primary iron and scrap by steel furnace type.

As item 3 has already been explained in chapter II, we will discuss only the basis used in this report for items 1 and 2.

Average Yields of Steel per Ton of Metallic Input

The average steel yield by furnace varies slightly depending on the proportions of cold pig iron, molten pig iron, and scrap used. For the industry as a whole we use yields which are based upon a study made by the U.N. and which are representative of the experience of advanced steel-producing countries. These are shown in table 39.

Table 39. Average Yields of Steel, Major Steel Processes

(In percent)

Process	Composition of charge		Yield	
	Fe	Scrap	Liquid steel	Ingots
Open hearth[a/]...	50	50	92.3	89.8
L.D.[a/]..........	70	30	91.1	88.6
Kaldo[a/].........	55	45	92.5	90.0
Electric........	5	95	94.8	92.3

a/ Hot charge.

Source: United Nations, Comparison of Steel-Making Processes (ST/ECE/Steel/4) 1962, table 20.

These yields are very close to the U.S. data as reported by the American Iron and Steel Institute (AISI), except in the case of the electric furnaces. Using the 1968 data of the AISI (the latest on raw material inputs), the open hearth shows scrap plus pig plus ore input (the latter taken as Fe input) equal to 73.230 million net tons, and an ingot steel output of 65.836 million net tons. This is equal to a yield of .8990 percent which compares to the U.N. figure of .8980. For the basic oxygen furnace the yield is .8811, which compares to the U.N. figure of .8860.

The 1968 AISI data for the electric furnace are inconsistent since they show an input of pig plus scrap of 16.757 million tons and an output of steel of 16.814 million tons, for a yield of 1.0034 (i.e., more output than input, which is impossible). Part of the explanation is that a large proportion of electric furnace steel consists of alloy and stainless, so that the alloy elements of nickel, chromium, vanadium, molybdenum, etc., are not counted in the inputs but are in the outputs. Also, the AISI figures are probably less complete for electric furnace output, a substantial proportion of which come from "mini mills," which are not completely covered by the AISI. If we take prior years 1961 to 1965, the electric furnace yield is about .963 compared to the U.N. figure of .923. Part of this discrepancy is due to the use by the U.N. of a 5 percent pig charge compared to a 1.5 to 2.00 percent pig charge in U.S. practice. It should be noted that for all processes the U.N. data show a loss of 2.5 percent in converting raw liquid steel to ingot steel.

Continuous Castings and Conventional Casting (Ingots)

In chapter II we noted the potential advantages of continuous casting compared to current methods. According to a recent study of the Business and Defense Services Administration, the gross (overall) effect of continuous casting, taking account of both nonrecoverable and recoverable losses, is a reduction in metallic raw material requirements. The raw material requirements per 100 tons of finished steel for continuous casting as compared to conventional methods are shown in table 40.

It should be observed that in conventional methods, raw liquid steel is first cast into ingots, whereas in continuous casting raw liquid steel goes directly to the casting machines to produce slabs, blooms, or billets. As ingots are an intermediate product, we are really seeking the requirements of scrap and pig iron per ton of finished steel. As we have noted, this varies depending on the proportion of finished steel made by using the continuous casting

Table 40. Comparison of Scrap and Pig Iron Requirements Per 100 Tons of Finished Steel for Conventional Methods and Continuous Casting

Scrap and pig iron requirements	Conventional methods	Continuous casting	Continuous casting as percent of conventional methods
	----- tons -------		
Gross scrap and pig iron used..........	158	133	84
Less home scrap...	336	19	53
Net purchased scrap and pig iron used..	122	114	93
Less nonrecoverable losses......	22	14	64
Finished steel produced...........	100	100	

Source: U.S. Department of Commerce, Business and Defense Services Administration, Office of Metals and Minerals, Iron and Steel Scrap -- Consumption Problems, March 1966.

process. It also varies somewhat depending upon the product mix of the finished steels produced. But this latter source of variation is very small, particularly as we do not foresee any radical shift in product mix, i.e., between proportions of flats and the various sectional products. We may therefore ignore the small changes which product mix variation will cause in the requirements of ferrous inputs per ton of finished steel.

Table 41 shows the difference in the metallic charge between conventional methods and continuous casting to make 1 ton of slab for the two major varieties of carbon steel, for alloy steels, and for stainless steel. "Killed" carbon steel is preferable for flat products which will be cold rolled.

Table 41. Metallic Charge per Ton of Rolled Slab[a] and Cast Slab[b]

(In tons)

	Total metal charge	Oxidation and nonrecoverable losses	Home scrap
Rimming carbon steel			
Rolled slab...	1.2553	.1240	.1313
Cast slab.....	1.1330	.1052	.0278
Killed carbon steel			
Rolled slab...	1.3670	.1447	.2223
Cast slab.....	1.1429	.1060	.1369
Low alloy steel			
Rolled slab...	1.4537	.1728	.2809
Cast slab.....	1.1621	.1227	.0394
Alloy steel			
Rolled slab...	1.5235	.2117	.3118
Cast slab.....	1.2008	.1484	.0524
Stainless steel			
Rolled slab...	1.5207	.2195	.3012
Cast slab.....	1.2225	.1584	.0641

a/ Conventional methods.
b/ Continuous casting.

Source: United Nations, Economic Aspects of Continuous Casting of Steel (ST/ECE/STEEL/23), 1968, pp. 153-155.

Table 42 shows the ratio of ingot steel per ton of steel shipments from 1960 to 1969. As shipments vary from year to year due to steelmill inventory, the ratio shows considerable variance from year to year. A 2-year moving average eliminates some of this variance and is closer to the true yield. This average shows a slight trend to lower yields (i.e., more ingot tons per ton of finished steel), which reflects a somewhat greater proportion of more highly finished steel products and higher alloy steel production. Tables 38, 41, and 42 allow us to check the accuracy of table 40 with respect to metallic inputs for conventional methods and continuous casting. Though some of the finished steel in table 41 was continuously cast, it was a very small proportion prior to 1968, less than 10 percent in 1968, and about 13 percent in 1969. Only small error is introduced if we use the 1966-67 moving average as the conventional ingot casting ratio to finished steel of 1.5032. The scrap plus pig charge necessary for 1 ton of finished steel can then be constructed as follows:

Tons of ingots per ton of finished steel..............	1.5032
Weighted loss of raw steel per ton of metallics1/.......	.0779
Total.......................	1.5811

According to table 40, 1.33 tons of pig iron and scrap are required to yield 1 ton of finished steel by continuous casting. We can check this figure in the following way: table 41 shows the metallic charge per ton of slabs. A weighted average of these yields is 1.1458 tons of metallics per ton of slab.2/ The next step is to determine the tons of slab (or bloom or billet) which yield 1 ton of finished product. The wastage from a continuously cast slab (bloom or billet) to the

1/ This is 1.00 minus the weighted yield shown in table 39. The weights used for the processes are the share of output we forecast for 1980: 60 percent, basic oxygen furnace; 25 percent, electric furnace; and 15 percent, open hearth.
2/ Weighted as follows: killed steel, 60; rimmed, 30; alloy, 10 (average alloy = 1.1800).

Table 42. Ratio of Steel Ingots, Tonnage Produced per Ton of Net Shipments of Steel, 1960-69

Year	Ratio	Two-year moving average
1960..................	1.3954	
		1.4388
1961..................	1.4822	
		1.4380
1962..................	1.3937	
		1.4199
1963..................	1.4461	
		1.4711
1964..................	1.4960	
		1.4574
1965..................	1.4187	
		1.4544
1966..................	1.4901	
		1.5032
1967..................	1.5163	
		1.4738
1968..................	1.4312	
		1.4680
1969..................	1.5048	
1960-69 average......		1.4575

finished product will be approximately the same as in the conventional ingot casting because the slab or bloom or billet, whether derived from rolling or continuous casting, will then proceed through the same further rolling processes. This results in the following tonnages:

Total metallics, conventional method, per ton of finished steel........................	1.5811
Total metallics per ton of rolled slab[1] (table 41)......	1.3468
Difference.....................	.2343

The difference above is the amount of metallics required per ton of finished steel due to the wastage from the slab stage to the finished rolled steel product. Since this is the same for either conventional or continuous casting, we then combine the tons of metallics per ton of continuous cast slab: 1.1458 + .2343, which equals 1.3801 compared to 1.3300, a difference of 3.8 percent. Another method is simply to estimate the amount of continuous cast slabs, blooms and billets required to make 1 ton of finished product. We estimate this yield to be 86 percent, or 1.1628 tons (of slabs, blooms, and billets) that are required to make 1 ton of finished product.[2] Thus total metallics for continuous casting per ton of finished product equals 1.1628 x 1.1458, or 1.3323 tons of metallics per ton of finished steel made by continuous casting. These two results are sufficiently close to allow us to use table 40 to calculate metallic requirements.

Total Metallics by Furnace Type and by Conventional and Continuous Casting

Using tables 39 and 40 we are able to derive the total metallics (primary iron, scrap) by furnace type

1/ Weighted rolled slabs (table 40); killed steel, 60; rimmed steel, 30; alloy steel, 10 (alloy steel = 1.5000).
2/ The yield from rolled slabs would not be as high since the surface quality of continuous cast slabs is much better and the slab is more homogeneous, resulting in lower losses of finished product.

and by casting method per ton of finished steel. This is shown in table 43.

Table 43. Total Pig Iron and Scrap per Ton of Finished Steel Required by Various Steelmaking Furnaces: Continuous Casting and Conventional Methods

(In tons)

Furnace type	Pig iron and scrap requirements	
	Conventional methods	Continuous casting
Open hearth......	1.580	1.327
L.D..............	1.592	1.336
Kaldo............	1.578	1.326
Electric.........	1.555	1.306

Source: Derived from tables 40 and 41.

Calculating Iron Ore Requirements

Given the requirements for primary iron, iron ore requirements to produce the required iron ore are calculated simply. Table 44 shows the consumption of iron ore (agglomerates, concentrates and direct ore) and other iron-bearing materials, together with coke and limestone, from 1960 to 1969. As table 44 shows, iron ore requirements per ton of pig iron produced are approximately 1.6 tons. However, the iron ore shown in table 44 contains less than 63 percent Fe which we have used for standard ore. Since hot metal (and PRO) contains normally about 94 to 95 percent Fe, and if there were no loss of Fe from input to output, the amount of 63 percent iron ore required to make 1 ton of hot metal containing 95 percent Fe is .95/.63 = 1.51 tons. There is, however, a loss of Fe in the process. An approximate calculation of this loss is given below:

Table 44. Consumption of Ore, Scrap, Mill Cinder, Limestone, and Coke Per Net Ton of Pig Iron Produced, 1960-69

(In net tons)

Products	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Iron ore and agglomerates a/	1.573	1.577	1.577	1.530	1.531	1.514	1.536	1.560	1.608	1.567
Scrap a/	0.042	0.043	0.044	0.046	0.043	0.044	0.043	0.039	0.036	0.039
Mill cinder, scale, etc...	0.094	0.091	0.094	0.091	0.091	0.083	0.062	0.063	0.057	0.059
Total.......	1.709	1.711	1.695	1.667	1.665	1.641	1.641	1.662	1.701	1.665
Limestone and dolomite b/ ...	0.303	0.301	0.282	0.284	0.274	0.279	0.268	0.257	0.241	0.244
Coke a/	0.749	0.708	0.690	0.669	0.655	0.656	0.641	0.631	0.624	0.626

a/ Based on total material charged less products recovered.
b/ Based on total limestone and dolomite charged directly into blast furnaces, plus tonnage consumed in the production of agglomerates.

Source: American Iron and Steel Institute, Annual Statistical Report 1969, table 39.

Item	Tons	Fe	Total Fe
Net iron ore and agglomerates[a].....	1.567	.614	.96214
Net scrap...........	.039	.62	.02418
Mill cinder and scale..............	.059	.40	.02360
Total...............			1.00992

a/ 90 percent of this consists of pellets, sinter, concentrates at 63 percent Fe, and 10 percent of direct shipping ore at 56 percent Fe.

Thus approximately 1.01 tons of Fe input result in .95 tons of Fe output (the percent of Fe in hot metal) or a loss of approximately 6 percent. Hence, for standard ore of 63 percent Fe content, 1.51 x 1.06 equals 1.601 tons of standard ore, to yield 1 ton of primary iron (hot metal, pig iron, PRO). To the extent that higher proportions of scrap, mill cinder and scale are used, less ore will be required. However, as table 44 shows, these materials have been declining per ton of pig iron produced. We have therefore used 1.6 tons of standard ore per ton of primary iron.[1]

Future U.S. Iron Ore Production

The United States has enormous deposits of iron ore, most of which is counted not as reserves but as "potential" ore (see appendix table 1). However, the high-grade deposits of the Lake Superior district (51+ percent Fe) are mostly depleted. Fortunately, the "taconites" of this region are capable of being converted to high-grade pellets and form the basis of U.S. production of iron ore, accounting for about 77 percent

1/ Increased production and efficiency are obtained when high-quality agglomerates are used, accounting for the lower use of mill scale and cinder, which have low Fe contents (25 to 40 percent), and relatively more gangue.

of total U.S. iron ore production. The major uncertainty of how much iron ore the United States will produce depends therefore on the relative cost of using U.S. agglomerates as compared to high-quality foreign ores and agglomerates.

Mesabi ore, as of January 1, 1971, on Lake Erie docks was quoted at a price of $11.17 per long ton (see appendix table 5). Since the base is taken at 51.5 percent Fe natural iron content, this is equivalent to 21.68 cents per long ton. Pellets were quoted as of that date on Lake Erie docks at 25.2 cents per long ton, about 16 percent more expensive than unagglomerated ore. However, the advantages of pellets are numerous. They are easier to handle; their uniformity facilitates loading and unloading with automated equipment; they are ideal for belt conveyors; and they are dry, and thus freezing is no problem in railway cars, ships' holds or storage piles. Since they contain more iron than most natural ores, less waste material is moved per unit of Fe. They have mechanical strength, unlike sinter which cannot easily be transported or stored for long periods without deterioration. Pellets made from hematite and magnetite are easier to reduce than most sinters.1/ As has previously been noted in chapter II, pellets improve the productivity of blast furnaces.

It should be observed that the prices quoted above do not necessarily equal the cost to U.S. steel companies. At least 85 percent of the iron ore and agglomerates consumed in the United States, whether produced in the United States or imported, are from mines and beneficiation facilities owned by steel companies -- the so-called "captive" mines. Their costs are probably lower than the above prices; in any case these prices do not cover the bulk of U.S. ores which are captive.

In 1969 the average value at the mine of usable ore was $10.34 per long ton. However, the Minnesota

1/ See United Nations, Economic Aspects of Iron Ore Preparation, 1966, p. 32ff.

ores (and agglomerates) which accounted for 63 percent of total U.S. shipments averaged $9.94 per long ton (derived from table 45), which at a 59 percent average Fe content yields a price at the mine of $16.85 per long ton of iron (in the ore) for Minnesota ores. Cost of transportation from the mine to Lake Erie docks, including loading and unloading, is about $2.50 per long ton, so that Lake Superior ores at Lake Erie docks should cost about $12.44 per long ton. This ore would average 59 percent Fe. Of course, most ores are now agglomerates and concentrates, and by 1980 we expect virtually all Lake Superior ores to be agglomerates, mostly in pellet form.

If transportation costs do not increase (in real terms) by 1980, and if transportation rates are not changed (to raise pellets above nonagglomerated ore per ton), then Lake Superior pellets should be transported from mine to Lake Erie docks in 1980 at about $2.50 per ton (1969 dollars). Since the average Fe content of Lake Superior pellets in 1980 will be at least 65 percent, then, assuming no change in the price (in 1969 dollars) of usable ores in 1980 from 1969, we can derive the cost per long ton of iron delivered to Lake Erie docks in 1980 as follows:

1. Cost at mine = $9.94 per long ton (59 percent Fe)
2. Pelletizing at 16 percent above cost of ore = $1.59 per ton1/

1/ This is based on the Lake Erie price differential previously noted. This is consistent with a U.N. estimate which places the capital cost for a pelletizing plant at between $6-$8 per annual ton of capacity depending upon whether it is magnetite (the lower) or hematite. If we take a 15-year depreciation period this amounts to about 46.7¢ per ton + 15 percent for profit and interest = 54¢ per ton. About $1.50-$2.00 per ton is given for operating costs. These are based upon 1965 data, and in view of the great advance made since then we believe these figures to be on the high side. They also are for pellet plants of 1 million ton capacity -- which under current installations is a small plant. U.N., Economic Aspects of Iron Ore Preparation, 1966, p. 70.

Table 45. Shipments of Iron Ore by States, 1965-69

(Quantity in thousands of gross tons; value in millions of dollars)

States	1965		1966		1967		1968		1969[a]	
	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value
Alabama........	1,495	8.2	1,508	8.7	1,472	8.3	1,151	6.7	1,018	6.0
Michigan.......	13,527	145.5	14,377	157.4	14,130	162.6	12,699	148.9	14,400	173.2
Minnesota......	50,873	459.3	55,133	499.4	49,457	468.6	51,275	508.8	56,500	562.0
New Jersey, New York, Pennsylvania, Virginia......	4,758	68.3	4,511	63.2	3,901	54.4	3,549	50.6	3,467	49.1
Utah...........	2,139	14.2	1,956	13.5	1,708	11.9	1,764	11.3	1,917	12.2
Wisconsin......	141	b/	b/	b/	b/	b/	b/	b/	b/	b/
Wyoming........	2,087	25.2	1,978	19.7	1,854	19.2	1,967	19.5	2,036	20.3
Other..........	9,454	83.7	10,578	92.3	9,893	92.5	9,529	90.6	10,416	105.0
Total........	84,474	804.5	90,041	854.1	82,415	817.5	81,934	836.4	89,754	927.7

a/ Preliminary figures.
b/ Included with other.

Source: Bureau of Mines, Department of the Interior.

3. Total cost of pellets at mine = $11.53 (65 percent Fe)
4. Cost of transportation = $2.50 per long ton
5. Cost at Lake Erie docks = $14.03 per long ton pellets
6. Cost per long ton iron (in pellet form) = $21.58 at Lake Erie docks.

If, for example, the usable ore were shipped to Lake Erie docks, the price per ton of iron (in ore) would be $9.94 + $2.50 = $12.44 (59 percent Fe), equal to $20.92 per long ton of iron (in ore) or a difference of 66 cents per ton. Clearly pelletizing will be done at the mine.

It is reasonable to assume that the real cost per ton of usable ore will stay constant at least until 1980. Though more tons of crude ore will be required per ton of usable ore, productivity (i.e., tons mined per man-hour) shows steady increase. Reno and Brantley of the U.S. Bureau of Mines estimate that 2.1 billion tons of iron (in ore) equivalent to about 10 billion tons of crude ore will be obtainable at the 1968 price ($15.40 per short ton).1/ This 2.1 billion tons of iron is their low estimate of primary iron demand to 2000.

We think that improvements will be made in pelletizing technology, which now is barely 15 years old. It was not until 1963 that pellet production in the United States exceeded 20 million tons per year. It is now over 60 million tons and continues to expand. We can expect that by 1980 pelletizing efficiency should be at least 20 percent greater than now, so that cost per ton of pelletizing should decline (in 1969 dollars) to about $1.30. Further, we expect that the real cost of Great Lakes transportation of iron ore and agglomerates will decline by 20 percent due to the modernization

1/ Reno and Brantley, "Iron," in Mineral Facts and Problems, U.S. Department of the Interior, Bureau of Mines Bulletin 650 (Washington, D.C.: Government Printing Office, 1970), p. 291.

of Great Lakes vessels (the use of 45,000-ton carriers, for example, compared to 20,000-ton carriers and less), improved high speed loading and unloading facilities designed to handle pellets. Thus, instead of $2.50 per ton, we should expect a total transportation cost from Lake Superior mines to Lake Erie docks of about $2.00 (1969 dollars). Making these adjustments, we obtain a cost at Lake Erie docks of $20.37 per long ton of iron (in pellets) for 1980 (in 1969 dollars).

The important question is whether such a price is attractive enough to induce U.S. steel companies to continue domestic iron ore production and pelletizing at a scale sufficiently large so that imports do not grow relative to domestic iron ore requirements. Reno and Brantley believe the price is attractive enough, and they forecast a constant 35 percent of imports of U.S. iron ore (primary iron) requirements. They believe that the present advantage of foreign ores, which is about $2.00 per ton delivered to seacoast locations (i.e., gulf and Atlantic ports), will persist to the year 2000. Some idea of the cost per long ton of iron (in ore) of foreign imports compared to the U.S. cost of Lake Superior ores delivered to Lake Erie docks1/ is shown in table 46.

It should be noted that the costs in table 46 are the value at port of discharge as declared by the importer. These imports are for the most part captive ore from Canada, Venezuela, and Liberia, and to a lesser extent all the other countries as well. As in the case of domestic captive ore, these values may not represent the total cost to the steel companies. Furthermore, since they include ocean transport costs, they are susceptible to change resulting from the use of more efficient transport vehicles and technology. It is nevertheless apparent that the gulf coast and eastern seaboard can be reached more economically from foreign locations than from Lake Superior. The only question that arises is whether the ores from Venezuela, Chile, Brazil, Australia, and Liberia will pentrate inland and

1/ The cost to Lake Michigan docks is approximately the same.

Table 46. Delivered Cost per Long Ton of Imported Iron Ore at Coastal Ports, and of U.S. Ore and Pellets at Lake Erie Docks

Country of origin	Delivered cost per long ton of ore	Percent Fe	Cost per long ton of Fe in ore
Canada........	$12.02	61	$19.70
Venezuela.....	8.61	62	13.89
Peru..........	12.68	65	19.51
Chile.........	7.93	64	11.94
Brazil........	8.68	66	13.15
Australia.....	12.52	63	19.87
Liberia.......	9.46	64	14.78
U.S. ore[a]....			20.92
U.S. pellets[a]			20.37

a/ At Lake Erie docks.

Source: Average values calculated from U.S. Bureau of Census data on volume and value of imports; values are average January-April 1971.

how far. The Pittsburgh region is within range by rail from the ports of Baltimore and Philadelphia. In addition, the Chicago-Gary area and plants along the Ohio river system may be in range from the ports of New Orleans and Mobile with transshipment by barge. The answer will depend on relevant ocean and inland transport costs. Further questions arise concerning the time that exporting countries will pelletize their ore, how expensive this will be compared to U.S. pelletizing costs, and the time and extent of direct reduction of foreign ores in the countries of origin. We cannot presently give well-founded answers to these questions.

Two further considerations are of importance. To the extent that the United States does not markedly increase its imports, it will be able to obtain a lower price for imported ores (i.e., concession costs for foreign ores owned by the United States will be lower). The second consideration lies in the political

instability in the South American and West African countries. Pelletizing capacity costs in these countries will be higher than in the United States since much more infrastructure investment will be needed (e.g., in transportation, power, water, and beneficiation equipment) in addition to pelletizing equipment. Thus 50 million tons of ore in pellets per year would probably represent an investment of over $500 million. Political instability is a significant factor in influencing such investment.

For projection purposes, subject to modification on the basis of separate evaluation of relevant transport costs, we have as a first resort adopted the following expedients:

1. Use the 1970 ratio of imports to requirements (production plus imports) for a suitable period. If we take the most recent year, 1970, this amounts to 31.2 percent. Note that the U.S. Bureau of Mines has used 35 percent for 1970-2000 for this ratio. But, as can be derived from table 47, the percentages of imports to requirements was 34 percent in 1965 and 34.6 percent in 1967. This table also shows a consistent decline since 1967.

2. Table 48 shows another relationship: the ratio of usable ore produced to pig iron produced in the United States. Figure 5 plots this ratio for both the United States as a whole and for Lake Superior and northern New York areas. As can be seen from the figure, there is a fairly smooth trend from 1950 to 1970 (which shows both curves reaching asymptotes), and -- significantly for our purposes -- the sharp decrease in the rates of decline coincides with the large production of pellets in the United States. The implication is that the cost of pellets in the United States (counting also the advantages of pellets in the blast furnace as compared to unagglomerated ores) is sufficiently favorable to warrant increases in pelletizing capacity dictated by pig iron requirements. The average Fe content of U.S. usable ore increased from 50.25 percent in 1953 to 59.00 percent in 1969, an average annual increase of about .5 percent. For 1980 the Fe content of usable ore should be about 63 to 64 percent, or approximately the basis we have used for standard ore.

Table 47. U.S. Production and Imports of Usable Iron Ore, 1940, 1950, 1955, and 1960-70

(In millions of long tons)

Year	Production	Imports	Percent imports of production
1940..............	73.7	2.5	3.39
1950..............	98.0	8.2	8.37
1955..............	103.0	23.4	22.72
1960..............	88.8	34.6	38.96
1961..............	70.7	25.8	36.49
1962..............	61.3	33.4	46.84
1963..............	72.8	33.3	45.74
1964..............	83.8	42.4	50.60
1965..............	87.4	45.1	51.60
1966..............	90.1	46.3	51.39
1967..............	84.2	44.6	52.97
1968..............	85.9	43.9	51.11
1969..............	88.3	40.8	46.21
1970[a/]............	88.8	40.3	45.38

a/ Preliminary figures.

Table 48. U.S. Usable Iron Ore and Pig Iron Production, 1950-70

Year	Usable ore (mil. long tons)	Pig iron[a/] (mil. net tons)	Usable ore/pig iron ratio
1950......	98.0	64.6	1.517
1951......	116.5	70.3	1.657
1952......	97.9	61.3	1.597
1953......	118.0	74.9	1.575
1954......	78.1	58.0	1.347
1955......	103.0	76.9	1.339
1956......	97.9	75.1	1.304
1957......	106.1	78.4	1.353
1958......	67.7	57.2	1.184
1959......	60.3	60.2	1.002
1960......	88.0	66.5	1.323
1961......	70.7	64.6	1.094
1962......	71.3	65.6	1.087
1963......	72.8	71.8	1.014
1964......	83.8	85.6	.979
1965......	87.4	88.2	.991
1966......	90.1	91.5	.985
1967......	84.2	87.0	.968
1968......	85.9	88.8	.967
1969......	88.3	95.0	.929
1970......	88.8	91.3	.973

a/ Excludes ferroalloys made in blast furnaces and electric furnaces.

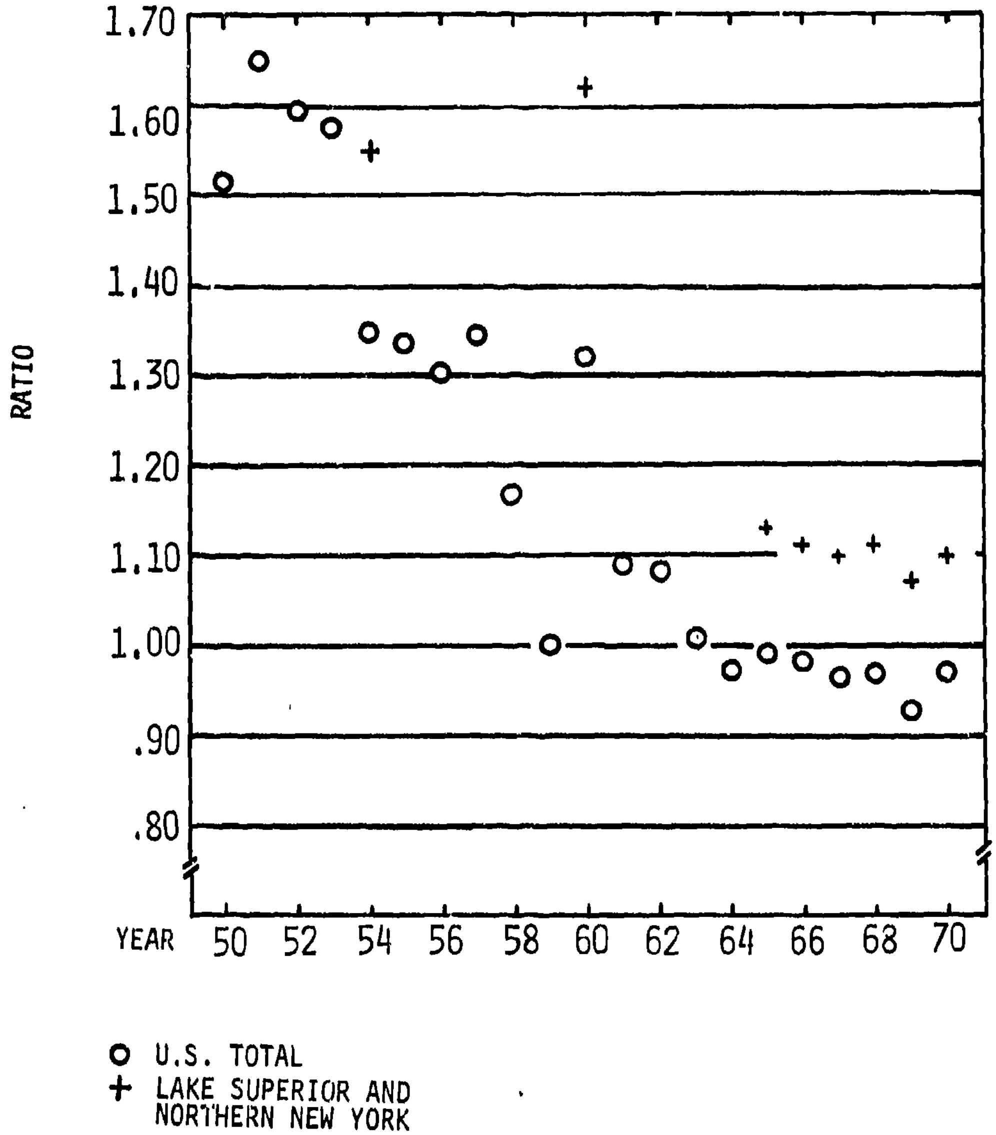

FIGURE 5. RATIO OF USABLE ORE PRODUCED IN THE UNITED STATES TO PIG IRON PRODUCED IN THE UNITED STATES, 1950-70, AND RATIO OF LAKE SUPERIOR ORE PRODUCTION TO LAKE SUPERIOR-DEPENDENT PIG IRON PRODUCTION

The major objection to this argument is that during the period 1961-70, very little pellets other than from U.S. captive mines in Canada were imported into the United States. Other exporters were not shipping many pellets. By 1980 they will be shipping more, and after 1980, relatively even greater amounts. It is obvious that such exporters will dominate all seacoast locations from the gulf coast to Atlantic ports. How far inland they will penetrate is not yet ascertainable. The ratio of .92 tons of iron ore per ton of pig iron production is the trend value of the total U.S. ratio. This ratio yields imports of approximately 35 percent of total requirements, which is also the estimate of Reno and Brantley of the Bureau of Mines, although it was derived in a different manner.

However, total U.S. figures derived in this manner are misleading for imports. This is due to the fact that the major iron ore consuming regions are deficit iron ore areas, while the West produces all the ore it requires plus over 3 million tons for export.

We must specifically estimate the pig iron requirement by region, together with the ore deficit expected in the region. For our purposes this is equivalent to eliminating far western iron ore requirements and production from the calculations, since as an export area it does not directly enter into the iron ore economy of the rest of the United States. The trend of the Lake Superior iron ore producing region (plus New York ore) per ton of iron produced shows a similar trend. We make use of this in chapter IV to estimate regional ore requirements, production and imports.

IV. DISTRIBUTION OF IRON ORE IMPORTS BY PORT AREA

Production of Pig Iron and Iron Ore by Region

The quantity of iron ore imports and their entry points in the United States depend on the amount of pig iron or primary iron which will be produced in the various iron- and steel-producing regions of the United States and on the domestic ore favorably situated relative to these producing areas. The major pig iron producing states and their production are shown in table 49. The percentage distribution is shown in table 50.

Geographical Shifts in Pig Iron Production

As table 50 shows, the proportion of pig iron produced by state of total U.S. production has shifted over the past 25 years. The noteworthy shifts, as the table shows, are in Pennsylvania, Alabama, Illinois, and Ohio, all of which have declined relatively by 15 percent or more since 1945. The sharp increases have been in Michigan, California, Colorado, Utah, and in Maryland, Kentucky, and Texas. New York has been relatively constant.

Two features of table 50 are worth noting. First, the great shifts took place in the 15 years after World War II (from 1945 to 1960). In the last decade the change has been very moderate. Ohio, in the past 10 years, has shown no change; Illinois, Pennsylvania and

Table 49. Production of Pig Iron by States
(In millions of net tons)

State	1945	1950	1955	1960	1965	1968	1969
Alabama......	3.58	4.35	4.92	3.54	4.20	4.38	4.89
Colorado, Utah and California..	1.64	2.65	3.56	3.74	4.88	4.92	5.03
Illinois.....	5.05	6.02	6.49	5.31	6.23	6.21	7.13
Indiana......	5.98	7.02	8.72	8.40	11.02	12.48	12.67
Kentucky, Tennessee and Texas...	.81	1.46	1.71				
Maryland and West Virginia....	3.52	5.20	6.09	7.99	10.88	10.77	12.07
Michigan and Minnesota...	1.92	2.83	4.00	4.98	7.53	7.32	7.64
New York.....	3.30	4.30	5.14	4.21	6.10	5.91	6.37
Ohio.........	11.26	12.51	15.37	11.79	15.41	15.80	16.91
Pennsylvania.	16.17	18.24	20.84	16.53	21.79	21.02	22.33
Total.......	53.23	64.58	76.84	66.49	88.04	88.81	95.04

Table 50. Percentage Distribution of Pig Iron Production by States

States	1969	1966	1963	1960	1955	1950	1945	Relative, 1945-69 (1945=100)
<u>Great Lakes</u>								
New York..............	6.70	7.09	5.95	6.33	6.69	6.66	6.20	108.1
Ohio..................	17.79	17.93	17.80	17.73	20.00	19.37	21.15	84.1
Indiana...............	13.33	13.07	13.81	12.64	11.34	10.87	11.23	118.7
Illinois..............	7.50	7.26	6.23	7.98	8.45	9.32	9.49	79.0
Michigan and Minnesota................	8.04	8.67	8.98	7.49	5.20	4.38	3.61	222.7
Subtotal............	53.36	54.02	52.77	52.17	51.68	50.60	51.68	103.3
Pennsylvania...........	23.50	23.69	24.06	24.87	27.12	28.24	30.38	77.4
Maryland, West Virginia, Kentucky, Tennessee, Texas............	12.70	12.15	12.11	12.01	10.15	10.31	8.13	156.2
Alabama................	5.15	4.80	5.44	5.33	6.40	6.74	6.73	76.5
Colorado, Utah, California................	5.30	5.35	5.62	5.62	4.63	4.10	3.08	162.3
Total............	100.00	100.00	100.00	100.00	100.00	100.00	100.00	

Source: American Iron and Steel Industry, <u>Annual Statistical Report</u>, Table 38.

Alabama have declined 5 percent or less over the last 10 years. Of the states which have shown the most marked increase, Michigan has increased only moderately from 1960, appearing to fluctuate between 8 and 9 percent of total pig iron production depending upon the variations in automotive production. The Far West, if anything, shows a slight decline from 1960, the decade high. Only in Indiana and in Maryland, Kentucky, and Texas has the increasing trend persisted, but even in these cases at a much slower pace than from 1945 to 1960. New York appears to have stabilized between 6 and 7 percent of total pig iron production. The second feature shown in table 50 is the stability of the combined Great Lakes region.

The underlying economic forces which follow explain these shifts in the steel industry. Integrated steel plant locations are generally selected to minimize the total cost of delivering steel to market, assuming all other conditions such as water supply, labor force, etc., are met. The three major elements are the cost of iron ore and coal at the steel plant site and the cost of delivering steel from the plant site to market. In the past any location at which the sum of two of these costs would be a minimum would deter determine the location of an integrated steel plant. Thus Pittsburgh was both low cost to markets and coal; Chicago, to markets and ore; Birmingham, Alabama, to coal and ore and so forth.

Shortly after World War II, transportation rates on finished steel were raised sharply relative to coal and iron ore, so that the weight of the transportation cost of finished steel in the equation increased. Efficiencies in the use of coal for power, in the production of coke, and in the coke rate lessened the importance of coal in the equation. Thus the balance of post-World War II economic and technological changes moved toward locations that were pulled more heavily by markets and iron ore than by coal. The great Pittsburgh steel-producing region was particularly vulnerable to these changes. The radius in which it could economically compete diminished. The Pittsburgh region covers Pittsburgh and the surrounding region including Weirton, Wheeling, Steubenville and Youngstown in West Virginia and eastern Ohio.

In addition to this general development, several specific factors occurred:

1. The great upsurge of automobile production after the war greatly increased the size of the Detroit market. Steel plants close to Detroit were more favorably situated than the Pittsburgh region with respect to markets and iron ore. Closer proximity to customer plants was also an advantage. Thus the great increase shown by Michigan from 1945 is explained. However, the auto industry will not expand in the future more rapidly than the increase in GNP, so that the rate of growth of Michigan steel and its share of total U.S. steel and pig iron production will probably stabilize at its recent level. Automotive production plants have also moved into many other regions close to steel and markets, thus lessening the importance of Michigan.

2. The core of U.S. industrial production utilizing steel -- the metals complex -- lies in the Midwest, primarily in the tier of states bordering the Great Lakes. Thus this region has been stable over the past quarter century and will very likely be so over the next quarter century. Its very size gives it economic stability.

3. The development of the great iron ore ranges of Venezuela after World War II provided a source of cheap iron ore to the seacoast location of Sparrows Point, Maryland; to the ocean access location of eastern Pennsylvania (Fairless Works) and to the plants of Bethlehem in southeastern Pennsylvania within easy reach of the ports. The great Middle Atlantic markets formerly served by the Pittsburgh region thus were easily penetrated by these locations. In addition, the seacoast New England area is closer to these Maryland and eastern Pennsylvania plants.

4. The construction of an integrated steel plant in both California and Utah during World War II and the rapid growth of California gave impetus to the growth of these areas -- which are also served by Sparrows Point and eastern Pennsylvania.

5. The growth of steel production in Texas and Louisiana was stimulated by the great growth of oil, natural gas, and petrochemical industries; by the

presence of cheap hydrocarbons; and by the easy access of these regions to cheap Venezuelan ore and other South American and West African ore supplies in these areas.

6. Because iron ore is cheaper to transport than steel, the abundant coal of the southern Illinois and Kentucky fields and the sizable local markets present in southern Ohio (Cincinnati and St. Louis) stimulated these regions to the detriment of the Pittsburgh region.

7. The decline of the Alabama region was primarily due to the increasingly high costs of the Clinton ores on which this industry was based. Its markets were also penetrated by the southern Illinois and southwestern Ohio River plants.

8. The Buffalo, New York, area has been relatively stable. Its water access to iron ore and to the richer ores of the Adirondack region, together with the diversified market area it serves, will probably allow it to maintain a fairly stable share of the total steel market. However, it faces severe competition from Cleveland and the nearby Canadian steel plants in Hamilton, Ontario.

In summary, one can expect the following trends:

1. The Pittsburgh region will continue to decline, but at a lesser rate than in the past.

2. The Great Lakes steel producers will probably stabilize at their recent percentage share.

3. The east coast producers will grow at the expense of the Pittsburgh region.

4. The Texas steel industry will continue to grow and show an increasing share.

5. The share of the far western steel industry will probably grow, but at a lower rate during the next decade than in the past. However, it is expected that after 1980 its growth will increase rapidly as a result of the direct reduction technology for which the Pacific coast provides favorable conditions. (See the discussion of this point in the subsequent section entitled "Pig Iron Production by Regions.")

6. The central steel producers (St. Louis, Cincinnati and Colorado) will probably maintain their current share of total output.

Geographic Shifts in Iron Ore Production

Table 51 shows the quantity and percentage distribution of iron ore produced in the major ore-producing regions of the United States over the past 30 years. U.S. iron ore production reached a peak in 1953 when 118 million long tons of iron ore were produced, of which the Lake Superior ores constituted 95.7 million tons or 81.1 percent of total output. In 1969 Lake Superior ores produced were only 68 million tons of a total of 89 million tons. Western ore has shown a large increase from 1 million tons in 1940 to 15 million tons in 1969. The Southeast (primarily Alabama) has declined greatly (from 7.4 to 1.5 million tons since 1940) while the Northeast, primarily the Adirondack ores of New York, have remained about the same.

The significance of these changes is that the Great Lakes pig iron producing region (including Pittsburgh, West Virginia and southern Ohio, which are all dependent upon the Lake Superior ores) is now a deficit region. The eastern seaboard iron producers have always depended, and are now completely dependent, upon foreign ores. The northeast ores are primarily New York ores, which go to the Buffalo steel producers, and are an addition to the Lake Superior and Canadian supplies on which Buffalo depends. Alabama is now heavily dependent upon foreign ores. Only the western ore-producing region has a surplus of ore relative to the needs of the steel producers dependent upon it, and exports some to Japan. The western region's distance from the deficit areas eliminates it as a potential source of supply to these areas.

The broad picture of U.S. iron imports and production is clear. Every major U.S. iron-producing region is a deficit area, expect for the States of Utah and Colorado and California. Maryland and eastern

Table 51. U.S. Iron Ore Production by Region
(In millions of long tons)

Regions	1940		1950		1955		1960		1965		1968		1969	
	Qty.	Pct.	Qty.	Pct.	Qty.	Pct.	Qty.	Pct.	Qty.	Pct.	Qty.	Pct.	Qty.	Pct.
Lake Superior..	61.5	83.4	79.6	81.2	83.2	80.8	71.8	80.9	66.4	76.0	66.2	77.0	68.4	76.7
Southeast....	7.4	10.0	7.5	7.7	7.1	6.9	4.3	4.8	2.0	2.3	1.5	1.8	1.4	1.6
Northeast....	3.6	4.9	4.5	4.6	4.7	4.6	4.1	4.6	5.2	5.9	4.0	4.7	3.8	4.3
West.....	1.2	1.6	5.9	6.0	7.0	6.8	4.6	5.2	13.1	15.0	13.4	15.6	15.0	16.8
Byproduct ore.....	--	--	.6	.6	1.0	1.0	3.9	4.4	.8	.9	.7	.8	.7	.8
Total...	73.7	100.0	98.0	100.0	103.0	100.0	88.8	100.0	87.4	100.0	85.9	100.0	89.2	100.0

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook.

Pennsylvania are now, and by 1980 Alabama will be, completely dependent on foreign ore. The Texas coast is completely dependent now and will be so in the future. The only major question is the extent of the deficit which will exist in meeting the requirements of the great bulk of the steel industry that were formerly supplied by Lake Superior ores via lake carrier and railroad from lake docks to steel plants in western Pennsylvania, West Virginia, inland Ohio, Kentucky and southern Illinois. As of now the deficit of this great region is met by Canadian captive ore shipped down the St. Lawrence Seaway to Lake Erie. The deficit of the gulf and Atlantic producers is met by ores from a variety of sources -- South America, West Africa and Canada -- which enter the United States through Baltimore, Morrisville (on the Delaware), Philadelphia, and the gulf coast ports. To determine the quantity of imports the following estimates must be made:

1. The percentage share of the pig iron and steel producing regions of the United States for 1980-2000.

2. The amount of ores and agglomerates which will be produced in the Lake Superior region, counting the Adirondack ores of northern New York.

Pig Iron Production by Regions

Table 52 contains the estimates of pig iron production by the three major regions (i.e., Great Lakes dependent steel plants, gulf and Atlantic plants, and all others). This latter category includes the Pacific Coast States and the Mountain States. As table 52 shows, the Great Lakes States proper have shown great stability in their share of total pig iron output. However, as we have discussed, the Pittsburgh region has declined and will continue to decline relative to other regions of the country. Since this production area is dependent upon Lake Superior ores, the Great Lakes region shows a moderate decline in share of 2.4 percent from 1970 to 2000.

The Gulf and Atlantic States, which have been increasing their share of pig iron production since the

Table 52. Pig Iron Production by Region, 1960, 1965 and 1969, and Estimated 1980, 1990, and 2000

(In millions of net tons)

Year	Great Lakes		Gulf-Atlantic		Other		Total
	Production	Percent	Production	Percent	Production	Percent	
1960.......	48.9	73.5	13.9	20.9	3.7	5.6	66.5
1965.......	63.7	72.4	19.5	22.1	4.9	5.6	88.0
1970 a/	65.2	71.4	21.2	23.2	4.9	5.4	91.3
1980.......	71.3	71.0	23.6	23.5	5.5	5.5	100.4
1990.......	85.7	70.0	29.0	23.7	7.7	6.3	122.4
2000.......	102.0	69.0	35.8	24.2	10.1	7.3	147.9
	Percent change in production						
1970-80....	9.4		11.3		12.2		
1980-90....	20.2		22.9		40.0		
1990-2000..	19.0		23.4		31.1		

a/ Preliminary figure.

Source:

decade of the 1950's, continue on our estimate to do so through the year 2000. However, the increase in share is moderate, rising from 23.2 percent in 1970 to 24.2 percent in 2000.

The "all other" category shows the largest gain in its share of total pig iron production after 1980. It is our belief that substantial production of primary iron largely through direct reduction processes will take place in the Pacific Coast and Mountain States after 1980. The region is large and growing; it is a substantial importer of finished steel from the rest of the United States and from Japan. Because the market for steel exists; because iron ore from California, Wyoming, Nevada, and possibly Alaska will be available, as are large supplies of coal (near Bellingham, Washington); and because hydroelectric power costs, particularly in the Pacific Northwest, will be relatively cheap (and nuclear plants will be more plentiful after 1980), conditions exist for a rapid growth in the area's production both of primary iron and steel. It is indeed not outside the realm of probability that PRO from the area may be shipped to the Midwest. These reasons account for the relatively rapid rise of the "other" category.

Since we have already forecast the total primary iron production for 1980, 1990 and 2000, the share distribution enables us to compute the absolute amounts of pig iron (primary iron) shown in table 52. Our basic problem is to estimate the production of usable ore in the Lake Superior region.

Production of Lake Superior Ore

As table 53 shows, Lake Superior ore (including also northern New York production) has declined since 1955, though in terms of iron content the decline has been less than shown because Fe content has steadily increased from about 54 percent to 59 percent in 1969-70. We expect that future production in this region will increase, but not enough to meet the requirements of the steel industry based upon it. As table 53 shows,

Table 53. Pig Iron Produced by Iron and Steel Plants Dependent on Lake Superior Ores, and Production of Iron Ore in Lake Superior Region and Northern New York, 1955-69, and Forecast 1980-2000

Year	Pig iron (mil. net tons)	Percent of total U.S. production	Iron ore (mil. long tons)	Iron ore/pig iron ratio
1955....	57.2	74.5	88.9	1.55
1960....	48.9	73.5	79.8	1.63
1965....	63.7	72.4	72.6	1.14
1966....	66.0	72.1	73.8	1.12
1967....	62.4	71.7	68.8	1.10
1968....	63.4	71.4	70.9	1.12
1969....	68.0	71.5	72.9	1.07
1970....	65.2	71.4	71.8	1.10
1980....	71.0	71.0	79.5	1.12
1990....	84.9	70.0	93.4	1.10
2000....	100.8	69.0	108.9	1.08

Note: Pig iron produced figures are approximate due to estimate of Pennsylvania production between western Pennsylvania (Pittsburgh) and eastern Pennsylvania.

the ratio of usable ore (in long tons) to pig iron production (in those iron and steel plants based on Great Lakes ores) has been fairly constant from 1965 to 1970. Part of the reason lies in ore economics, which we discussed in chapter III. The ore mines of both the Lake Superior region and Canada are, for the most part, captive. Railroads, to some extent, are also captive, particularly U.S. Steel's roads from the Mesabi mines to Duluth and from Lake Erie to Pittsburgh, and the iron ore railroads in Quebec and Labrador. The Great Lakes vessels are also captive. Further, the rail haul of iron ore from either Baltimore or other North Atlantic ports to supply the Pittsburgh, West Virginia and Mahoming Valley producers is more costly than iron ore hauled from the Great Lakes to these regions. The rail route which proceeds down the Mahoming Valley is much shorter and a less difficult haul than from Atlantic or gulf ports to Pittsburgh. For all these reasons we believe that the Great Lakes based steel industry will find it cheaper to obtain most of its imports from Canada, and to maintain a fairly constant balance between the proportion of its requirements to be met from Lake Superior production and from Canada unless significant economies in inland rail and water transport are achieved over existing practice. We have estimated the ratios for 1980-2000 as shown in table 53 on these considerations.

Estimate of Iron Ore Requirements, Production and Deficit by Region

Table 54 consolidates all our previous estimates (of finished steel, primary iron, iron ore, and regional iron production) into iron ore requirements, production and deficits by region. Table 55 shows the same for the United States as a whole.

Several features are worth noting:

1. The Atlantic-gulf region, although it accounts for only 24 percent of total iron ore requirements, accounts for approximately 60 percent of total import requirements. The balance is the deficit of the Great Lakes dependent iron and steel industry. The Mountain and Pacific Coast States are self-sufficient in iron ore.

Table 54. Estimates of Iron Ore Requirements, Production and Deficit by Region, 1980, 1990, and 2000

(In millions of long tons of standard ore)

Region	1980	1990	2000
Great Lakes			
Requirements.............	101.9	122.4	145.7
Production...............	79.9	94.3	110.2
Deficit..................	22.0	28.1	35.5
Percent deficit of requirements..............	21.6	23.0	24.4
Gulf-Atlantic			
Requirements.............	33.7	41.4	51.1
Production...............	1.0	1.0	1.0
Deficit..................	32.7	40.4	50.1
Percent deficit of requirements..............	97.0	97.6	98.0
Total deficit.............	54.7	68.5	85.6
Total requirements........	135.6	[illegible]3.8	196.8
Percent deficit of requirements..............	40.3	41.8	43.5
Other			
Requirements.............	7.9	10.9	14.1
Production...............	15.0	19.0	23.0
Deficit..................	0.0	0.0	0.0

Source: RRNA, 1971.

Table 55. Forecast of U.S. Iron Ore Requirements, Production, Imports and Exports, 1980, 1990 and 2000

(In millions of long tons of standard ore)

Item	1980	1990	2000
Requirements............	143.5	174.8	211.2
Production..............	95.9	114.3	134.2
Imports.................	54.7	68.5	85.6
Exports[a]/...............	7.1	8.1	8.9
Percent imports of requirements.............	38.1	39.2	40.5

a/ Exports are the difference between "other" production and "other" requirements shown in table 54.

Source: RRNA, 1971.

2. For the two deficit regions, iron ore imports constitute approximately 40 percent of their total requirements in 1980 and 43 percent in 2000.

3. Imports constitute 38.1 percent of total U.S. requirements in 1980 and 40.5 percent in 2000.

According to the U.N. estimate previously referred to, imports will amount to approximately 36 percent of U.S. requirement in 1980.[1]/ The Reno-Brantley (U.S. Bureau of Mines) estimate previously mentioned was a constant 35 percent of total U.S. iron ore requirements from 1970 to 2000. The U.N. estimate for U.S. production of iron ore in 1975 is 94 to 95 million tons (60 percent Fe content).[2]/ This compares to our estimate of 96+ million tons for 1980 (63 percent Fe) or 100 million tons of equivalent Fe content. The critical question, however, is how much will be produced in the Lake Superior region.

1/ United Nations, World Market for Iron Ore (ST/ECE/Steel/29), 1968, Table 91, p. 164.
2/ Ibid., p. 151.

For reasons already mentioned the entire requirement for iron ore of the Atlantic-gulf iron and steel producers must be met by foreign iron ore. (We have postulated a nominal amount of 1 million tons of ore production for this region.) This region, according to our forecasts, will require 34, 41 and 51 million long tons of standard iron ore (63 percent Fe) for the years 1980, 1990 and 2000 respectively. However, because of the increasing amounts of pellets, concentrates and PRO which will be produced in the exporting countries, the iron content of these ores will be continually increasing over the years. In accordance with the estimates in chapter II of this report, the actual tonnage of agglomerates and ores imported by this region will be less than shown. The actual tonnage of imports we estimate for the Atlantic-gulf region is as follows:

Year	Actual ore	Standard ore	Difference
	----- mil. of long tons -----		
1980.....	30.5	32.7	-2.2
1990.....	35.6	40.4	-4.8
2000.....	43.2	50.1	-6.9

The Great Lakes region deficit is the one most subject to uncertainty. Its iron ore requirements are about three times the magnitude of the Atlantic-gulf region. The economics of iron ore mining, pelletizing, and PRO production in this region compared to the importing of more iron ore from Canada and other areas is a very close question. We have projected a growing reliance on imports.

The usable iron ore production we have projected for the Lake Superior region is of course dependent upon the installation of pelletizing capacity. In 1970 somewhat over 60 million tons of pellets were produced in the United States and about 16 million tons in Canada. As of January 1, 1971, the trade press reported that U.S. Steel was installing two new pelletizing lines at its Mintac plant in Minnesota with an additional capacity of 3 million tons. Under consideration was a 4 million ton plant at Hibbing, a 2 million ton plant by

Butler Brothers-Taconite Company, and expansion by National Steel of its Minnesota plants. Thus over 9 million tons of capacity was either under consideration or in construction.1/

In the light of these figures our projection of 79.9 million tons of standard ore for 1980 does not appear unreasonable. It may be too low. Similar plans and construction are underway in Quebec, Labrador and Newfoundland by the Iron Ore Company of Canada, a company with major U.S. steel company ownership. This company will expand its iron ore productive capacity from 20 million tons to 33 million tons by 1972. Of this total, 16 million tons will be pellets. A new 6 million ton pellet plant will be built at Sept Iles, bringing total pelletizing capacity there to 23 million tons annually.2/ Of interest is the consideration of a 223-mile slurry pipeline to bring ore to Sept Iles for pelletizing and concentrating. It seems clear that as of now the Great Lakes dependent steel producers count on the Lake Superior and eastern Canadian ores as their long-term supply source. A balanced expansion of both areas now seems the most likely prospect.

Sources of Iron Ore Imports

The two largest sources of imported iron ore are Canada and Venezuela. Virtually all the iron ore imported from these two countries is produced in mines owned by or under long-term concessions to U.S. steel companies. Moreover, both these countries are most economically situated with respect to the U.S. markets they serve (eastern Canada to the U.S. Great Lakes ports; Venezuela to the eastern seaboard and the gulf coast). A great deal of Canadian iron ore is as low grade as the Lake Superior ores. Like those ores, it is mostly recovered by open cut mining and is economically beneficiated and pelletized. The huge investment by U.S. steel companies in mines, railroads, docks, and beneficiation and pelletizing capacity virtually guarantees

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1/ Iron and Steel Engineer, January 1971, p. D27.
2/ Ibid.

that eastern Canada (and some areas in western Ontario fairly close to the Minnesota ranges and also within easy reach of Lake Superior) will continue to be the preferred source of imported iron ore for use in the U.S. Great Lakes iron and steel industry. However, as the import figures show, almost 30 percent of eastern Canadian ore imported by the United States enters Atlantic ports as well. Most of these ores come from Labrador, eastern Quebec, and Newfoundland ports on the North Atlantic.

Venezuelan ore is of high iron content (60+ percent Fe), but as it has a substantial proportion of fines, increasing proportions of it will be pelletized as well as converted to PRO. U.S. Steel and Bethlehem Steel own very large iron ore reserves in Venezuela as well as the railroads which bring the ore to the Orinoco River for export. Both these companies will import all the ore required for their Maryland and eastern Pennsylvania steel plants, as well as for U.S. Steel's Texas and Alabama plants. The Government of Venezuela owns the largest deposit of iron ore in Venezuela and, as noted, is engaged in building direct reduction facilities. We can expect that a large amount of noncaptive Venezuelan iron ore will be available to U.S. steel companies.

Table 56 shows the theoretical costs of iron ore as of 1975, delivered to Mobile or Baltimore (or, in effect, to any port on the gulf or Atlantic coast) as calculated by the U.N. It should be noted that these theoretical costs are not market prices, but the costs from mine to market as estimated by the U.N. These costs moreover do not indicate the relative quality of the ore, i.e., its reducibility in the blast furnace. Since ocean transport costs are based on a 65,000 d.w.t. carrier for all origin countries, these theoretical delivered costs are subject to some variation in practice depending on the vessel size actually used or to be used and the round-voyage cargo characteristics. Nevertheless, these costs are good indicators of the relative attractiveness of the various sources of iron ore to U.S. steel producers in the Atlantic-gulf region. All of the South American producers as well as the West African countries can be counted on as suppliers of the Atlantic-gulf region. Of the countries shown, U.S.

Table 56. Aggregate Theoretical Costs of Standard Iron Ore Delivered to Mobile or Baltimore from Exporting Countries, 1975

Country	Assumption A[a]		Assumption B[b]	
	Dol. per metric ton	Index[c]	Dol. per metric ton	Index[c]
Canada.......	7.19	134	7.56	140
Venezuela....	5.36	100	5.39	100
Peru.........	6.45	120	6.19	115
Chile........	7.08	132	6.72	125
Brazil.......	7.56	141	7.55	140
Liberia......	6.53	122	6.38	118
Sierre Leone.	7.30	136	7.29	135
Gabon........	8.47	158	8.37	155
Sweden.......	8.87	165	9.47	176
Australia....	12.12	226	11.02	204

Note: Ocean transport costs assume vessel of 65,000 d.w.t.
a/ Assumption A is based on theoretical costs as calculated by U.N. for 1975 (U.S. 1968 dollars).
b/ Assumption B is based upon an assumed increase of 10 percent in the f.o.b. price of iron ore and a 20 percent decrease in ocean shipping costs (U.S. 1968 dollars).
c/ Venezuela = 100.0.

Source: United Nations, The World Market for Iron Ore (ST/ECE/STEEL/24), 1968, p. 196 and 199, Tables 118 and 122.

steel companies have participation in Canada, Venezuela, Brazil, Peru, Chile, Liberia, and Australia. The situation in Chile and Peru is somewhat clouded at the moment for political reasons.

Table 57 shows the total imports of iron ore into the United States by country of origin in the past 10 years. Table 58 shows the percentage distribution of these imports.

U.S. Ports of Entry

Table 59, based upon U.S. customs data, shows the percentage distribution by U.S. coastal zone of entry for each exporting country during 1968 and 1969. As can be seen, the Great Lakes ports are served almost exclusively from Canada, and the northeast coastal zone is the major importer from all sources except Canada. As shown in table 60, these imports are almost entirely through the ports of Philadelphia and Baltimore. On the gulf coast, the principal ports of entry are Mobile and Houston.

Table 57. Imports of Iron Ore by Countries of Origin, 1960-69
(In thousands of gross tons)

Country	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969[a]
Brazil.......	1,461	889	1,299	781	1,055	2,279	2,723	1,623	1,257	1,233
Canada.......	10,595	9,683	16,825	18,891	24,854	23,756	23,941	24,214	26,338	19,004
Chile........	3,942	2,604	3,400	2,679	2,712	2,660	2,268	1,365	1,441	1,783
Liberia......	907	715	757	1,310	2,873	2,769	3,390	3,099	2,942	3,144
Mauritania...	--	--	--	--	133	113	107	4	--	--
Mexico.......	150	123	145	1	22	10	--	--	--	--
Nigeria......	--	--	--	--	72	23	--	--	--	--
Peru.........	2,758	1,209	573	290	580	957	1,043	879	925	1,003
Sweden.......	94	78	32	37	93	57	82	148	232	155
Venezuela....	14,555	10,478	10,328	9,231	9,954	12,273	12,592	12,820	10,313	13,751
Other........	116	26	50	43	60	206	113	439	493	685
Total.......	34,578	25,805	33,409	33,263	42,408	45,103	46,259	44,611	43,941	40,758

a/ Preliminary figures.

Source: American Iron and Steel Institute, Annual Statistical Report, Table 50.

Table 58. Percent of Total Iron Ore Imports by Country of Origin, 1960-69

Country	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Brazil........	4.23	3.45	3.89	2.35	2.49	5.05	5.89	3.64	2.86	3.03
Canada........	30.64	37.52	50.36	56.79	58.61	52.67	51.75	54.28	59.94	46.63
Chile.........	11.40	10.09	10.18	8.05	6.40	5.90	4.90	3.06	3.28	4.37
Liberia.......	2.62	2.77	2.27	3.94	6.77	6.14	7.33	6.95	6.70	7.71
Peru..........	7.98	4.69	1.72	.87	1.37	2.12	2.25	1.97	2.11	2.46
Venezuela.....	42.09	40.60	30.91	27.75	23.47	27.21	27.22	28.74	23.47	33.74
Other.........	1.04	.88	.67	.25	.89	.91	.66	1.36	1.64	2.06
Total........	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Calculated from data in table 57.

Table 59. Percent of Total Import Tonnage of Iron Ore by U.S. Port Destination and by Country of Origin, 1968 and 1969

Country of origin and year	Zone 1 -- Northeast coast inc. Virginia	Zone 3 -- Gulf coast, Florida to Texas	Zone 6 -- Great Lakes	Zone 4 -- California	Zone 5 -- Oregon and Washington	Total
<u>Canada</u>						
1968...........	23.3	4.9	71.8	--	--	100.0
1969...........	23.6	4.1	72.3	--	--	100.0
<u>Venezuela</u>						
1968...........	74.9	25.1	--	--	--	100.0
1969...........	78.9	21.1	--	--	--	100.0
<u>Peru and Chile</u>						
1968...........	71.8	28.2	--	--	--	100.0
1969...........	65.7	30.8	--	--	3.5	100.0
<u>Brazil</u>						
1968...........	61.1	36.6	--	2.3	--	100.0
1969...........	65.5	34.5	--	--	--	100.0
<u>West Africa</u>						
1968...........	88.8	12.2	--	--	--	100.0
1969...........	91.9	6.0	2.1	--	--	100.0

Source: Special tabulation by RRNA of data in U.S. Department of Commerce, <u>U.S. Waterborne General Imports</u>, Bureau of Census Document SA305.

Table 60. U.S. Imports of Iron Ore by Port of Entry, 1969

Port	Short tons (1,000)	Percentage
Philadelphia, Pennsylvania...	12,295.3	28.9
Baltimore, Maryland..........	10,541.7	24.8
Mobile, Alabama..............	4,575.8	10.7
Cleveland, Ohio..............	3,215.4	7.5
Conneaut, Ohio...............	2,270.2	5.3
East Chicago, Indiana........	1,921.8	4.5
Gary, Indiana................	1,703.4	4.0
Detroit, Michigan............	1,056.9	2.4
Chicago, Illinois............	948.9	2.2
Ashtabula, Ohio..............	839.5	1.9
Houston, Texas...............	752.8	1.7
Buffalo, New York............	697.1	1.6
Baton Rouge, Louisiana.......	407.3	.9
Toledo, Ohio.................	345.6	.8
Huron, Michigan..............	247.9	.5
Camden, New Jersey...........	186.5	.4
Portland, Oregon.............	140.6	.3
Lorain, Ohio.................	138.5	.3
Newport News, Virginia.......	105.7	.2
New Orleans, Louisiana.......	102.6	.2
Ponce, Puerto Rico...........	6.2	.0
Tacoma, Washington...........	3.5	.0
New York, New York...........	.1	.0
Total........................	42,503.3	

Source: Special tabulation by RRNA of data in U.S. Department of Commerce, U.S. Waterborne General Imports, Bureau of Census Document SA305.

APPENDIX

Appendix table 1. Iron Ore Reserves and Resources of the United States by Region

(In millions of long tons)

Region	Reserves ore	Potential ore	Total resources
Lake Superior			
Minnesota	1,814	38,581	40,395
Michigan	405	17,224	17,629
Michigan and Wisconsin	36	18,996	19,032
Wisconsin	--	49	49
Total	2,255	74,850	77,105
Northeastern			
New York	21	932	953
Pennsylvania	79	5	84
New Jersey	--	16	16
Maine	--	317	317
Total	100	1,270	1,370
Southeastern			
Alabama	2,848	2,366	5,214
Georgia	52	2,015	2,067
Tennessee	50	1,453	1,503
Virginia	--	492	492
Mississippi	16	--	16
Total	2,966	6,326	9,292
Central Gulf			
Texas	174	--	174
Missouri	305	4	309
Oklahoma	1	1	2
Louisiana	162	--	162
Total	642	5	647
Central-Western			
Montana	66	283	349
South Dakota	--	493	493
Colorado	7	98	105
Utah	446	--	446
New Mexico	124	15	139
Wyoming	444	274	718
Total	1,087	1,163	2,250
Western			
Arizona	103	439	542
Nevada	168	--	168
California	156	1	157

continued--

Appendix table 1. Iron Ore Reserves and Resources of the United States by Region continued--

(In millions of long tons)

Region	Reserves ore	Potential ore	Total resources
Oregon................	3	1	4
Washington............	6	2	8
Total................	436	443	879
Alaska.................	8	11,272	11,280
Hawaii.................	--	1,024	1,024
Total U.S.[a].........	7,494	96,353	103,847

a/ Exclusive of large reserves of taconite ores for which data are not available for publication. It is believed by the authors of this chapter that a minimum of 3 billion tons of these taconite ores have been proven as a source of ore for beneficiation plants which are in operation or are under construction.

Source: Compiled by the U.S. Geological Survey for the United Nations iron ore survey, 1969.

Appendix table 2. Comparison of Percentage Shares of AISI Districts Computed by Time Trend of Shares and by Projection of Total Steel Ingot Production of Each District as a Linear Function of GNP and Time, 1980

AISI steel district	1965 actual percentages	1980	
		Least squares time trend of percentages	Multiple correlation of GNP and time
Northeast Coast...	13.9	16.3	13.3
Buffalo...........	5.4	5.0	5.5
Pittsburgh........	19.7	12.6	19.8
Youngstown........	8.6	3.1	9.8
Cleveland.........	5.1	6.1	5.6
Detroit...........	7.2	10.6	8.1
Chicago...........	20.0	21.7	19.2
Cincinnati........	4.8	6.1	4.7
St. Louis.........	2.6	4.3	2.2
Southern..........	5.8	6.9	5.5
Western...........	6.4	7.4	6.1

Note: Percentages will not add to 100 due to rounding.

Appendix table 3. Iron Ore Reserves and Resources of the World

(In millions of tons)

Region	Reserves ore	Potential ore	Total resources	Reserves of recoverable iron (Fe)
	-------- long tons	----------	----------	short tons
United States.......	10,494[a/]	96,353	106,847	2,000
Canada..............	35,727	87,988	123,715	11,730
Mexico, Puerto Rico, Central America....	573	198	771	380
South America.......	33,5[illegible]	57,478	91,039	18,330
Europe..............	20,964	12,598	33,562	8,530
U.S.S.R.............	108,755	190,740	299,495	31,000
Africa..............	6,693	24,113	30,806	3,380
Middle East, Asia, and Far East[b/].....	17,027	53,344	70,371	11,160
Australia, New Zealand, New Caledonia.........	16,535	c/	16,535	10,210
Total............	250,329	522,812	773,141	96,720

a/ Including 3 billion tons taconite and 600 million tons recoverable iron (Fe) estimated by authors of this chapter.
b/ Exlcusive of the Asiatic part of the U.S.S.R.
c/ Vast.

Source: United Nations iron ore survey, 1969.

Appendix table 4. Current Domestic Expansion Programs in Electric Furnace and Continuous Casting by Major Steel Companies, 1970

Company	Electric furnace		Continuous casting
	No.	Unit capacity	
Armco			
Butler, Pa.	3	165 ton[a]	C.C. slab caster[a]
Houston, Tex.	1	175 ton	--
Kansas City, Mo.	1	175 ton[a]	--
Middletown, Ohio	-	--	C.C. slab caster
Sand Springs, Okla.	1	70 ton[a]	--
Bethlehem			
Steelton, Pa.	3	150 ton[a]	--
Colorado Fuel & Iron			
Pueblo, Colo.	E.F. Shop		--
Inland Steel			
East Chicago, Ind.	2	175(?) ton[a]	Billet casting[a] Slab casting
Jones & Laughlin			
Aliquippa, Pa.	-	--	6 strand C.C. (billets)[a]
Northwestern Steel and Wire	1	400 ton[a]	--
Lukens			
Coatesville, Pa.	-	--	Single strand slab casting
National Steel			
Detroit, Mich.	-	--	C.C. blooms[a]
Republic Steel			
Chicago, Ill.	4	250 ton[b]	--
U.S. Steel			
Chicago, Ill.	2	250+ ton	Billet casting
Baytown, Tex.	2	250 ton	Slab casting
Fairless Hills, Pa.	2	250 ton	C.C. facilities (blooms)

a/ Denotes completion in 1970.
b/ Denotes 2 completions in 1970 and upgrading and enlarging 2 existing furnaces to 250-ton heats.
Source: Iron and Steel Engineer, January 1971, pp. D4-D7.

Appendix table 5, Lake Superior Iron Ore Prices at Lake Erie Docks

(In dollars per long ton)

Date	Old Range		Mesabi	
	Bessemer	Nonbessemer	Bessemer	Nonbessemer
1948...........	6.60	6.45	6.35	6.20
1949...........	7.60	7.45	7.35	7.20
1950...........	8.10	7.95	7.85	7.70
1951-52........	8.70	8.55	8.45	8.30
Sept. 17, 1952.	9.45	9.30	9.20	9.05
Mar. 19, 1953..	10.10	9.95	9.85	9.70
July 1, 1953...	10.30	10.15	10.05	9.90
1954...........	10.30	10.15	10.05	9.90
Mar. 1, 1955...	10.40	10.25	10.25	10.10
Jan. 1, 1956...	11.25	11.10	11.00	10.85
Jan. 30, 1957..	11.85	11.70	11.60	11.45
Apr. 1, 1962 a/.	11.05	10.90	10.80	10.65
Jan. 1, 1963 b/.	11.05	10.90	10.80	10.65
Jan. 29, 1964 c/	10.95	10.80	10.70	10.55
Jan. 1, 1970...	11.20	11.05	10.95	10.80
Jan. 1, 1971...	11.57	11.42	11.32	11.17

Note: Prices are based on transportation rates in effect as of early January 1968.

a/ Prices established on two grades: Mesabi taconite sinter, $12.85; fines under one-half inch, $10.20.

b/ Less 5 percent vessel freight refund for full year.

c/ Pellets at 25.2¢ per unit national iron.

Source: Metal Statistics 1970: The Purchasing Guide of the Metal Industries, 63rd ed., The American Metal Market Company (New York, 1970).

ANNEX A-4. IMPORTS OF ALUMINUM RAW MATERIALS (BAUXITE AND ALUMINA)

CONTENTS

INTRODUCTION

The basic raw material from which primary aluminum is commercially produced is bauxite. Under existing technology an intermediate refining stage is essential in which the raw bauxite is reduced to alumina. Metallurgical bauxite contains approximately 50 to 55 percent aluminum oxide; alumina is aluminum oxide in the form of powder containing only about 0.5 percent impurities.1/ Thus the production of aluminum metal involves essentially the production of the bauxite, its transportation to a plant for refining to alumina, the alumina refining process, the transportation of the alumina to an aluminum reduction plant, and the reduction to aluminum.

Approximately 2 tons of bauxite are required to produce 1 ton of alumina, and approximately 2 tons of alumina are required to produce 1 ton of aluminum. Thus a ton of aluminum may be regarded as the equivalent of 4 tons of bauxite and 2 tons of alumina.

In 1969, 87 percent of the bauxite consumed in the United States for the production of alumina was imported from foreign sources.2/ In addition, the United States was a net importer of 935,500 tons of alumina, so

1/ U.S. Department of the Interior, Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970, pp. 439-440.
2/ U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1969, p. 202.

that the degree of dependence of the primary aluminum-producing industry in the United States on foreign sources of raw materials was somewhat in excess of 87 percent (probably between 90 to 95 percent). The precise degree of dependence cannot be calculated because data are not available on the consumption of imported alumina.

Bauxite is also imported for consumption by the abrasive, chemical, and refractory industries, but the quantities are relatively small, accounting for approximately 5 percent of total imported bauxite consumption in 1969.1/ In view of the relative unimportance of these other uses, projections of import requirements for alumina and bauxite in this report are confined to the requirements of the aluminum industry.

Aluminum consumption requirements in the United States are supplied from three basic sources: production of primary aluminum, involving the import of aluminum raw materials; foreign imports; and secondary recovery of aluminum from sources of both new and old aluminum scrap. Thus, the present and future requirements for ocean transportation and related port facilities incidental to the fulfillment of U.S. consumption requirements for finished aluminum are a function of the balance between indigenous production and imports of bauxite on the one hand, and the form in which the deficit is to be imported (bauxite, alumina, or aluminum) on the other. These relative proportions are and will continue to be a function of the relative magnitude and quality of bauxite reserves in the United States and abroad, the structural characteristics of the aluminum industry, the relative cost characteristics of alternatives with respect to the location of alumina and aluminum plants, and the policies of the governments of foreign countries where the principal reserves of bauxite are found.

1/ Ibid.

I. STRUCTURAL AND GEOGRAPHICAL CHARACTERISTICS OF THE ALUMINUM INDUSTRY AND ITS RAW MATERIAL SOURCES

The aluminum industry is characterized by a high degree of corporate concentration of the production of primary aluminum and by a high degree of vertical integration of the three major stages of production, i.e., bauxite, alumina, and aluminum. In 1970 Alcoa, Reynolds, and Kaiser accounted for over 70 percent of total primary aluminum production in the United States, with the balance distributed among eight other companies (table 1). The entry of a fourth company took place only in 1955, and new companies have continued to enter the industry continuously since that year, with three new entries in 1969-70.

The degree of vertical integration of the industry and the geographical and locational characteristics of its bauxite, alumina, and aluminum production operations are presented in tables 2, 3, and 4. All of the 6.8 million tons of alumina capacity in the United States are owned by major primary aluminum producers (table 3). The same producers and some of the smaller aluminum companies similarly have extensive overseas bauxite exploratory and production operations, and in some cases alumina production facilities as well (see the appendix).

Quantitative data on overseas production and shipments of bauxite and alumina by U.S. companies are not available. However, table 4 shows, by company, the foreign country of origin of bauxite, the location of alumina plants receiving bauxite from each source, and the location of aluminum reduction plants receiving alumina from each alumina plant location. Four of the

Table 1. U.S. Production of Primary Aluminum by Company, Selected Years, 1950-70
(In short tons)

Producers	1950	1955	1960	1965	1968	1969	1970
Alcoa........	369,750	706,500	853,250	950,000	1,200,000	1,325,000	1,325,000
Anaconda......	--	60,000	65,000	100,000	175,000	175,000	180,000
Consolidated..	--	--	--	62,000	140,000	140,000	140,000
Eastalco......	--	--	--	--	--	--	85,000
Harvey........	--	--	60,000	87,000	91,000	91,000	91,000
Intalco.......	--	--	--	--	255,000	265,000	265,000
Kaiser........	143,000	428,200	609,500	650,000	690,000	710,000	710,000
National Southwire....	--	--	--	--	--	7,300	180,000
Ormet.........	--	--	180,000	184,284	240,000	240,000	240,000
Revere........	--	--	--	--	--	--	56,000
Reynolds......	238,500	440,000	701,000	725,000	895,000	935,000	945,000
Total.......	751,250	1,634,700	2,468,750	2,758,284	3,686,000	3,888,300	4,217,000

Note: Capacities shown are as reported for December 31.

Source: The Aluminum Association, Aluminum Statistical Review, 1970.

Table 2. Estimated Primary Aluminum Capacity by Region, Company, and Plant Location, 1971

(In thousands of short tons)

Location	Capacity
Northwest	
Alcoa:	
Vancouver, Washington...........	115
Wenatchee, Washington...........	175
Anaconda:	
Columbia Falls, Montana.........	180
Harvey:	
Dalles, Oregon..................	91
Goldendale, Washington..........	25a/
Intalco:	
Ferndale, Washington............	260
Kaiser:	
Mead, Washington................	206
Tacoma, Washington..............	81
Noranda:	
New Madrid, Montana.............	70
Reynolds:	
Longview, Washington............	200
Troutdale, Oregon...............	100
Northwest:	
Warrenton, Oregon...............	b/
Total...........................	1,503
Percent of U.S. total..........	33.2
Gulf coast	
Alcoa:	
Point Comfort, Texas............	185
Rockdale, Texas.................	280
Conalco:	
Lake Charles, Louisiana.........	35
Kaiser:	
Chalmette, Louisiana............	260
Reynolds:	
Corpus Christi, Texas...........	111
Total...........................	871
Percent of U.S. total..........	19.3

continued--

Table 2. Estimated Primary Aluminum Capacity by Region, Company, and Plant Location, 1971 continued--

(In thousands of short tons)

Location	Capacity
Ohio Valley	
Alcoa:	
Evansville, Indiana...............	250
Kaiser:	
Ravenswood, West Virginia.........	163
Ormet:	
Hannibal, Ohio....................	240
National Southwire:	
Hawesville, Kentucky.............	180
Total............................	833
Percent of U.S. total...........	18.4
Tennessee Valley	
Alcoa:	
Alcoa, Tennessee.................	200
Conalco:	
New Johnsonville, Tennessee.......	140
Revere Copper and Brass:	
Scottsboro, Alabama..............	112
Reynolds:	
Sheffield, Alabama...............	221
Total............................	673
Percent of U.S. total...........	14.9
Arkansas	
Reynolds:	
Arkadelphia.......................	63
Jones Mills.......................	122
Total............................	185
Percent of U.S. total...........	4.1
Maryland	
Eastalco:	
Frederick........................	85
Percent of U.S. total...........	1.9

continued--

Table 2. Estimated Primary Aluminum Capacity by Region, Company, and Plant Location, 1971 continued--

(In thousands of short tons)

Location	Capacity
North Carolina	
Alcoa:	
Badin.........................	115
Percent of U.S. total.........	2.5
New York	
Alcoa:	
Massena.......................	130
Reynolds:	
Massena.......................	128
Total.........................	258
Percent of U.S. total.........	5.7
Total United States.............	4,523
Percent of U.S. total...........	100.0

a/ Expanding to 100 in 1972.
b/ Scheduled but not in production.

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, 1969. Data updating table 14 supplied by Non-Ferrous Metals Division, Bureau of Mines, during telephone conversation.

Table 3. U. S. Alumina Plant Capacities by Region, Company, and Plant Location, 1969

(In thousands of short tons)

Location	Capacity
Gulf coast	
Reynolds:	
San Patricia, Texas	1,186
Alcoa:	
Point Comfort, Texas	900[a]
Kaiser:	
Baton Rouge, Louisiana	985
Gramercy, Louisiana	620
Ormet:	
Burnside, Louisiana	550
Alcoa:	
Mobile, Alabama	950
Interior	
Alcoa:	
Bauxite, Arkansas	400
Reynolds:	
Hurricane Creek, Arkansas	840
Offshore	
Harvey:	
St. Croix, Virgin Islands	350
Total	6,781

a/ To be expanded to 1,080,000 short tons in 1971.

Source: U. S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1969, p. 200.

Table 4. Bauxite and Alumina Sources of U.S. Alumina and Aluminum Plants by Company

Company	Bauxite source	Where converted to alumina	Where converted to aluminum
Alcoa............	Surinam	Mobile, Alabama	Alcoa, Tennessee Badin, North Carolina Massena, New York Evansville, Indiana
		Surinam	Vancouver, Washington Wenatchee, Washington
	Surinam, Dominican Republic and Jamaica	Point Comfort, Tex.	Point Comfort, Texas Rockdale, Texas Wenatchee, Washington
	Arkansas	Bauxite, Arkansas	Evansville, Indiana Vancouver, Washington Wenatchee, Washington
Anaconda Aluminum.	--	Buys alumina from Kaiser in Baton Rouge/Gramercy, La.	Columbia Falls, Montana
Conalco..........	--	Buys alumina from Swiss Aluminum, Ltd.	New Johnsonville, Tennessee
Harvey Aluminum...	Guinea	St. Croix, V.I.	The Dalles, Oregon
Intalco:			
Amax............	--	Buys alumina from Alcoa subsidiary in Australia	Ferndale, Washington
Howmet-Pechiney..	Australia (buys from Conalco)	Queensland Alumina	

continued--

Table 4. Bauxite and Alumina Sources of U.S. Alumina and Aluminum Plants by Company continued--

Company	Bauxite source	Where converted to alumina	Where converted to aluminum
Kaiser..........	Jamaica	Baton Rouge/ Gramercy, La.	Chalmette, Louisiana Mead, Washington Ravenswood, W. Va. Tacoma, Washington
	Australia	Queensland Alumina	Mead, Washington Tacoma, Washington
Ormet...........	Surinam (buys from Billiton)	Burnside, Louisiana	Hannibal, Ohio
Reynolds.........	Arkansas and Guyana	Hurricane Creek, Arkansas	Arkadelphia, Arkansas Jones Mills, Arkansas Massena, New York
	Haiti and Jamaica[a]	Corpus Christi, Texas	Corpus Christi, Texas Longview, Washington Sheffield, Alabama Troutdale, Oregon

a/ Reynolds has shipped Jamaican bauxite to Hurricane Creek. It is not presently doing this, but will do so again in the future.

Source: Phillip Farin and Gary G. Reihsamen, Aluminum - Profile of an Industry (New York: McGraw-Hill Metal Week, 1969), p. 25.

smaller companies are identified as purchasing bauxite or alumina from other companies.

The locational pattern of each of the three stages of production has its own distinct characteristics, reflecting the fundamental economic considerations relevant to each. Bauxite, naturally, tends to be produced and supplied from countries having resources which are relatively advantageous in terms of quantity, quality, location, and accessibility. Until the present these sources have been predominantly in the Caribbean -- specifically Jamaica, the Dominican Republic, and Haiti -- and two South American mainland countries in the Caribbean -- Surinam and Guyana.

Alumina plants have tended to be located in the United States, although overseas plants are located in Surinam and Australia. Nearly 80 percent of the alumina capacity in the continental United States is located in the Gulf Coast States of Texas, Louisiana, and Alabama at areas accessible to ocean transportation. The balance is located in Arkansas, where the plants are supplied almost wholly with bauxite from Arkansas mines. In addition, a plant in the Virgin Islands processes bauxite from Guinea for shipment to aluminum plants in the United States and abroad (table 3).

Thus the locational characteristics of alumina plants in the United States have been determined principally by the location of the raw material sources; that is, they are located either at the point of bauxite production or in coastal areas readily accessible to the ocean transport of bauxite. However, location in the United States does require the shipment of twice as much bulk cargo as would be involved if bauxite were processed into alumina at the point of production and the alumina were shipped directly to aluminum reduction plants. This increased ocean transportation cost is understood to be offset by savings in other costs, particularly in the fixed capital costs of plant location in the United States as opposed to the Caribbean.1/

1/ Phillip Farin and Gary G. Riehsamen, Aluminum -

To the extent that it may be economically advantageous to process bauxite into alumina at overseas sources, it would be logical to expect that this would have some influence on the location of future additions to alumina plant capacity required to supply the needs of the U.S. aluminum industry.

The locational pattern of the aluminum-producing industry is of equal importance to that of the alumina industry for purposes of the present study, because of the alternative of supplying the bulk alumina requirements from overseas sources as opposed to the predominant existing practice of supplying from alumina plants in the United States. The present locational pattern has largely been governed by the relative cost of electric power in different regions on the one hand and the location of aluminum markets on the other. Thirty-five percent of the estimated aluminum production capacity of the United States in 1970 was located in the Pacific Northwest, and approximately 30 percent was located in the Tennessee and Ohio Valleys (table 2).

Electric power costs to aluminum producers in the Pacific Northwest, where power is purchased from the Bonneville Power Administration, are the lowest in the nation. Although power costs in the Ohio and Tennessee Valleys are higher than those in the Pacific Northwest, they are lower than those in many other parts of the nation. In addition, the Ohio and Tennessee Valleys offer the advantage of closer proximity to the principal midwestern and eastern alumina markets. Plants in the Tennessee Valley have access to power sold by the Tennessee Valley Authority, and both the Tennessee and Ohio Valleys have the economic advantage of relative proximity to sources of coal required for the production of electric power.

Table 5 shows a comparison prepared by the Bonneville Power Administration of the raw material and power costs for aluminum produced at plants in these

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Profile of an Industry, (New York: McGraw-Hill Metal Week, 1969), p. 150.

Table 5. Comparison of Delivered Costs in Chicago for Aluminum Produced in the Pacific Northwest and the Ohio and Tennessee Valleys

(in dollars)

Region	Costs						
	Alumina		Petroleum coke and pitch	Power		Transporting ingot to Chicago	Total delivered costs
	Per ton	Per 1.9 tons		Per Kwh (mills)	Per 15,000 Kwh		
Pacific Northwest							
Producer buying Bonneville power and using alumina transported by:							
Rail............	12.26	23.29	5.05	2.1	31.50	21.46	81.30
Ocean...........	5.00	9.50	5.05	2.1	31.50	21.46	69.51
Ohio Valley							
Producer generating power from coal........	8.95	17.01	2.23	3.5	52.50	5.85	77.59
Tennessee Valley							
Producer buying TVA power........	5.35	10.17	3.47	4.2	63.00	14.20	90.84

Source: Phillip Farin and Gary G. Reihsamen, Aluminum - Profile of an Industry (New York: McGraw Hill Metal Week, 1969), p. 153.

three regions, as well as the cost of transporting aluminum ingot to Chicago. These figures show that the Pacific Northwest producers, whether receiving alumina by rail or by ocean transport, have an advantage in the Chicago market over the producers in the Tennessee Valley, and that producers receiving alumina by ocean transport have a substantial advantage over both Tennessee Valley and Ohio Valley producers. The cost of power is $31.50 per ton of aluminum in the Pacific Northwest, $52.50 in the Ohio Valley, and $63.00 in the Tennessee Valley.

To the extent that these estimates are valid and that these cost relationships continue, there appears to be a strong economic incentive to favor the Pacific Northwest as the location of a substantial share of the additional aluminum capacity to be constructed in this country. However, the data are deficient in that they do not show this area's relative position with respect to other cost items, including the raw material costs for alumina, and they also fail to distinguish between the ocean transport cost to the Pacific Northwest for alumina shipped from U.S. and Caribbean sources and for that shipped from Australia.

On the basis of objective analysis of available data, it is not possible to determine the future locational pattern of aluminum-producing facilities in the United States. Relative costs, particularly for electric power and transportation, are subject to unpredictable change. The cost of electric power from thermal sources, for example, has already risen considerably because of increases in the cost of fossil fuels and the cost of generating nuclear power in the Eastern and Midwestern United States. If the Bonneville Power Administration's pricing of power to aluminum producers in the Pacific Northwest for their future additions to capacity continues to be based essentially on hydroelectric costs rather than thermal costs, it is quite possible that the cost advantage of the aluminum producers in that region over producers in other regions will be widened.

II. POLITICAL AND ECONOMIC FACTORS INFLUENCING THE LOCATION OF ALUMINA AND ALUMINUM CAPACITY OVERSEAS

Several important influences at work are expected to result in the overseas location of new alumina and aluminum plant capacity required to serve the U.S. market. As stated earlier, there may already be an economic advantage to the location of alumina plants in the Caribbean. Important new sources of bauxite are being developed in Guinea and Ghana in Africa, and in Australia, where this economic advantage may be even greater because of greater distances and other economic factors. As shown in the appendix, U.S. aluminum companies already have in operation and are planning construction of additional alumina capacity in Australia, Jamaica, Surinam, Ghana, Guinea, and Germany. In addition, U.S. companies own aluminum capacity in Canada, Mexico, Surinam, Venezuela, Norway, the United Kingdom, Ghana, India, and Australia.1/

Apart from economic considerations, policies of foreign governments are expected to increasingly influence the location of U.S. alumina and aluminum capacity abroad. These policies take the form of inducements to, or compulsion (where possible) on, U.S. aluminum companies to locate their production capacity in foreign countries. Inducements take the form of special tax concessions or preferential electric power rates. However, the most important future influence is expected to be the enforcement of policies by the bauxite-producing countries aimed at having the processing of

1/ U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1969, pp. 164-67.

bauxite into alumina and aluminum located in these countries in order to enhance their economic benefits from the exploitation of their natural resources. Such policies have become sufficiently important and widespread to lead the Bureau of Mines to observe that "there is a high probability that within the next ten years foreign countries with the largest known reserves of bauxite will export alumina and, perhaps, aluminum nearly exclusively."1/

1/ U.S. Department of the Interior, Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970, p. 461.

III. WORLD BAUXITE RESERVES

World reserves of bauxite as estimated by the U.S. Geological Survey are shown by country in table 6. For purposes of this study and its interest in the future sources of supply of aluminum raw materials to the United States, the points to be noted are the relative insignificance of U.S. reserves and the overwhelming quantitative position of Guinea and Australia. These two countries combined account for more than half of total world reserves, including those of the Soviet bloc countries and the People's Republic of China.

Imports of Bauxite and Alumina by Country of Origin

Imports of bauxite and alumina by country of origin for 1965 through 1970 are shown in tables 7 and 8. Table 8 also shows total exports of alumina, which reached a level in excess of 1 million short tons in 1970 and which are a quantitatively significant component of the U.S. requirement for imports of bauxite. The predominance of Caribbean countries as sources of bauxite, with 97 percent of the total in 1970, and of Jamaica, with over 60 percent, is evident from table 8.

Equally evident and significant is the comparative stabilization of imports of bauxite, while imports of alumina increased by more than tenfold between 1965 and 1970, to 2.6 million tons.

From 1965 to 1970, Australia emerged as a source of alumina supply and in 1970 accounted for nearly one-

Table 6. Apparent World Bauxite Reserves, 1967

Region	Bauxite[a]	Aluminum equivalent[b]
North America		
United States:		
Arkansas............	44	8.8
Southeastern States.	1	.2
Total.............	45	9.0
Caribbean Islands		
Dominican Republic and Haiti...........	85	17.0
Jamaica..............	600	120.0
Total...............	685	137.0
South America		
Brazil...............	40	8.0
Guyana...............	80	16.0
French Guiana........	70	14.0
Surinam..............	200	40.0
Total...............	390	78.0
Europe		
Austria..............	1	0.2
France...............	70	14.0
Greece...............	84	16.8
Hungary..............	150	30.0
Italy................	24	4.8
Rumania..............	20	4.0
Spain................	7	1.4
U.S.S.R. (including Soviet Asia)........	300[c]	60.0
Yugoslavia...........	200	40.0
Total...............	856	171.2
Africa		
Ghana................	290	58.0
Guinea...............	1,200	240.0
Mozambique...........	2	0.4
Malawi...............	60	12.0
Sierra Leone.........	30	6.0
Total...............	1,582	316.4

continued--

Table 6. Apparent World Bauxite Reserves, 1967
continued--

Region	Bauxite[a]	Aluminum equivalent[b]
Asia		
China, mainland.......	150	30.0
India.................	64	12.8
Indonesia.............	20	4.0
Malaysia:		
Peninsular Malaysia..	10	2.0
Sarawak.............	5	1.0
Turkey................	30	6.0
Total................	279	55.8
Oceania		
Australia.............	2,000	400.0
Palau Islands.........	5	1.0
Total................	2,005	401.0
Total for world........	5,842	1,168.4

a/ Metric or long tons, dry basis; however, many estimates used in compilation failed to designate type of tons used and whether tonnages had been converted to dry basis.
b/ Short tons.
c/ Estimate probably includes much low-grade bauxite that would be classed as potential resources in other countries and possibly aluminous rocks other than bauxite.

Source: U.S. Department of the Interior, Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970, pp. 446-447, reprinted from U.S. Geological Survey Bulletin 1228, 1967.

Table 7. U.S. Bauxite Imports[a/] (as shipped) by Country of Origin, 1965-70
(In thousands of short tons)

Country	1965	1966	1967	1968	1969	1970
Jamaica...........	8,558.8	8,639.2	9,032.7	8,276.8	9,508.9	10,004.6
Surinam...........	3,318.0	3,920.0	3,437.5	3,208.3	3,154.4	3,273.4
Dominican Republic/Haiti........	1,755.9	1,255.9	1,526.0	1,582.4	2,015.5	2,028.3
Guyana....	97.2	365.0	426.0	436.7	373.1	355.3
Other.............	495.9	114.6	132.7	172.7	405.0	392.0
Total............	14,255.8	14,294.7	14,544.9	13,676.9	15,456.9	16,054.1

a/ Excludes imports into Virgin Islands, and imports of calcined bauxite.

Source: U.S Department of Commerce, Bureau of the Census, U.S. Imports for Consumption and General Imports, TSUSA Commodity and Country. Report FT246, 1965-70 Annual (Washington, D.C.: Government Printing Office, 1966-71).

Table 8. Alumina Imports by Country of Origin, 1965-70
(In thousands of short tons)

Country	1965	1966	1967	1968	1969	1970
Australia...............	--	16.8	308.7	697.8	1,309.8	1,189.6
Surinam.................	15.5	196.7	398.2	465.5	402.6	345.7
Jamaica.................	43.3	85.6	130.3	108.5	103.9	867.8
Other...................	167.8	189.4	115.1	44.5	96.1	156.7
Total imports..........	226.6	488.5	952.3	1,316.3	1,912.4	2,554.8
Exports[a/]...............	317.8	323.2	548.4	859.5	976.9	1,058.7
Net alumina imports....	-91.2	165.5	403.8	456.8	935.5	1,496.1

a/ Excludes exports from the Virgin Islands.
Source: See table 7.

half of total imports, with most of the balance coming from the Caribbean. Imports of alumina, which in 1965 were a bauxite equivalent of less than 0.5 million tons, exceeded 5 million tons bauxite equivalent in 1970, equal to one-third of bauxite imports. Thus, the trend toward conversion of bauxite to alumina at the source of production in this comparatively short period of time was very pronounced, and the magnitudes were quantitatively significant.

Imports of Bauxite and Alumina by Port

U.S. imports of bauxite and alumina by port of entry in 1969 are shown in table 9. Consistent with the locational characteristics of the alumina plants discussed earlier, virtually all bauxite imports enter through ports on the gulf coast in Texas, Louisiana, and Alabama. Five ports have receipts in excess of 1 million tons, the range being from 2.2 to 4.3 million tons.

On the other hand, virtually all alumina imports are received in Pacific Northwest ports. Quantities of course are very much smaller than for bauxite, and only three ports have receipts approximating 0.5 million tons.

Table 9. Bauxite and Alumina Imports by Port and Region, Shipping Weight for 1969[a]

(In thousands of short tons)

Region and port	Bauxite calcined and not calcined	Alumina
Gulf coast		
Baton Rouge, Louisiana..	4,342.0	--
Corpus Christi, Texas...	3,416.2	--
Port Lavaca, Texas......	3,090.3	--
Mobile, Alabama.........	2,313.8	--
Gramercy, Louisiana.....	2,205.6	--
New Orleans, Louisiana..	558.8	73.3
Other..................	126.2	--
Subtotal..............	16,052.9	73.3
Northwest		
Portland, Oregon........	15.3	115.2
Vancouver, Washington...	13.0	479.1
Bellingham, Washington..	--	528.5
Longview, Washington....	--	46.3
Tacoma, Washington......	--	532.9
Other..................	--	24.3
Subtotal..............	28.3	1,726.3
Northeast		
Baltimore, Maryland.....	101.0	--
Other..................	99.0	--
Subtotal..............	200.0	--
Total...................	16,281.2	1,799.6

a/ Excludes imports by liner or tanker.

Source: Tabulated from U.S. Department of Commerce, Bureau of the Census, U.S. Waterborne Imports of General Merchandise, Report SA 305.

IV. PROJECTION METHODOLOGY AND ASSUMPTIONS

This study projects the apparent consumption for aluminum in the United States for 1980 and 2000, the first essential step in the projection of aluminum raw material imports. Total apparent consumption is the primary production of aluminum, adjusted for imports and secondary recovery, exports, and stock changes.

Once apparent consumption has been established, total net imports of bauxite, alumina and aluminum can be established by subtracting from apparent consumption the production of aluminum from domestically produced bauxite and from secondary sources. The resulting total net import figure can then be converted to a bauxite-alumina equivalent by subtracting the net imports of aluminum metal. The resulting bauxite and alumina import components are then estimated separately.

In measuring the various supply-demand components in this study, data have been expressed in terms of their aluminum content unless specifically stated otherwise. Aluminum content was converted to gross weight of alumina by a factor of two and into gross weight of bauxite by a factor of four. Bauxite shipping weight requirements average approximately 12 percent more than dry weight consumption due to free moisture content.

Aluminum Metal Apparent Consumption

During the decade of the 1960's, the consumption of primary aluminum in the United States grew at a rate of about 8 percent annually. Among private sources

familiar with the industry there seems to be general agreement that the demand for aluminum will continue to rise about 8 percent annually during the next 5 years.1/ The situation from 1980 on is much less clear, and there are differences of opinion, with some sources estimating a continued 8 percent annual growth rate while others predict growth rates ranging from a low of 4 percent to a high of 7.4 percent.2/

For this study, it is assumed that growth in aluminum demand will decline progressively from an average growth rate of 8 percent to 4 percent in 1990, remaining at 4 percent to the end of the century. After 1990 the growth in aluminum consumption would roughly equal the growth in GNP.

Reasons for projecting a declining growth rate are persuasive. The past and present growth rates achieved by the aluminum industry are due to price stability, displacement of other materials and limited competition from other metals or other materials.

Price stability of aluminum is due to the availability of high-grade bauxite and power at stable costs and technologic improvements in processes. At the projected aluminum consumption growth rate, the need to utilize some lower grade bauxite will contribute to higher costs for aluminum.3/

The high input of electric power will not substantially change; however, present low-cost power will

1/ Phillip Farin and Gary G. Reihsamen, op. cit. pp. 82 and 83.
2/ Booz-Allen Applied Research, Inc., Forecast of U.S. Ocean-borne Foreign Trade in Dry Bulk Commodities, prepared for the U.S. Department of Commerce, Maritime Administration, March 1969; and U.S. Department of the Interior, Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970, page 454. See also table 14.
3/ Phillip Farin and Gary G. Reihsamen, op. cit., p. 154.

not be available in the future. The higher cost of fossil fuels and nuclear power and the declining sources of low-cost hydropower will substantially raise the cost of power per pound of product. This factor is expected to induce U.S. producers to build reduction plants outside the United States close to the sources of power and/or raw materials.

In the past two decades technological improvements in processes have accounted for an increase in alumina derived from bauxite. These improvements seem to have reached a maximum level with present technology. Attempts at direct reduction1/ by four major aluminum producers have proven unsuccessful, and all research in this direction has been tabled.

The growth rate of aluminum consumption in the primary user industries has been far greater than the growth of these consuming industries, indicating that aluminum has displaced other materials in these applications. This rapid growth shows signs of tapering off.

Related to aluminum's displacement of other materials is the threat of its being displaced by nonmetals as well as by other metals attempting to regain some of their lost markets. Steel, tin, and copper industries have embarked on major research projects designed to strengthen competition with aluminum and to pose a serious threat to the future expansion of aluminum. However, the largest threat to aluminum is from plastics. Plastics production has increased 12 to 14 percent annually in recent years. The three largest aluminum consuming sectors (construction, transportation and packaging) have shown the largest increase in plastic use. Many plastics competing with aluminum are roughly equivalent or lower in cost on a weight basis, and are much less expensive on a volume basis.2/

It is therefore assumed that while the consumption of aluminum in the United States will rise

1/ Ibid., p. 154.
2/ Ibid., p. 157.

substantially during the next 30 years, the factors enumerated above will gradually force its growth rate down to the level of the growth rate for the economy as a whole, or about 4 percent annually. This decline will, however, not fully be realized until the closing years of the century.

Secondary Recovery of Aluminum

For some years now secondary recovery has been growing at a slightly higher rate than primary production. Because of the increasing production of aluminum and the availability of scrap, the importance of secondary recovery has been growing and will continue to increase in proportion to the expanding aluminum industry. In the 1950's the secondary supply was approximately 16 percent of the total domestic aluminum supply; at present, secondary recovery accounts for 18 to 19 percent of the total supply (primary and secondary production plus imports).

With the increasing awareness of the need for conservation and the expanding availability of scrap sources, secondary supply will continue to grow. However, it should be noted that about 80 percent of secondary supply is presently derived from new scrap.1/ If old scrap becomes an increasingly important factor, the secondary supply could rise to 21 percent by 1980 and to 25 or 30 percent by 2000.2/ In this study it is assumed that secondary supplies will reach a level of about 21 percent of total aluminum supplies by 1980 and 25 percent by 2000.

Aluminum Metal Imports

Generally, lower cost power, as well as political and economic considerations in less developed

1/ U.S. Department of the Interior, Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970, p. 449.
2/ Booz-Allen, op. cit., p. 188.

countries, will encourage the production of aluminum in those countries, many of which are now major U.S. bauxite and/or alumina sources. Some of this new capacity will undoubtedly be built by U.S. aluminum companies, and some of it in lieu of capacity which under current conditions of supply of bauxite and alumina would have been built in the United States. In addition, the expected rapid rise in electrical power requirements in the United States, coupled with the limited additional hydro sources, the higher cost of fossil fuels and nuclear energy, and environmental considerations, may force U.S. companies to locate additional needed reduction capacity in other less developed regions.

The imports of aluminum metal, especially in the latter part of this century, are thus likely to rise more rapidly relative to imports of either bauxite or alumina. This trend will to some extent tend to be offset by the increasing demand for aluminum outside the United States which will have to be supplied from similar foreign sources.

For 1970-80 we have estimated that one-quarter of the new reduction capacity required by U.S. companies to meet the country's growing aluminum demand will be built outside the United States, thus raising the imports of metal by an equivalent amount. For 1980-2000, the estimate is one-half of such capacity requirements. Under this formula, U.S. imports of aluminum metal will rise to 1.38 million tons in 1980 and 6.1 million tons in 2000 (table 10).

Aluminum Metal Exports

U.S. exports of aluminum metal are not expected to rise and may even decline during the next three decades because aluminum production capacity is being expanded rapidly in developing and developed countries. American companies are adding to this increasing foreign capacity in order to take advantage of lower production costs and more favorable trades and tariff conditions. For purposes of this study it is assumed that exports will remain at approximately 1970 levels.

Table 10. U.S. Apparent Aluminum Consumption, 1960 and 1965-70, and Estimated Probable for 1980 and 2000

(In thousands of short tons)

Consumption	1960	1965	1966	1967	1968	1969	1970	1980	2000
Primary aluminum production.....	2,014.5	2,754.5	2,968.4	3,269.3	3,255.0	3,793.1	3,976.2	6,756.5	11,490.5
Secondary recovery.	442.5	835.5	918.0	905.5	1,031.0	1,056.0	983.0	1,850.0 a/	5,450.0 a/
Aluminum imports..	196.3	600.0	652.1	515.2	755.9	534.5	448.7	1,380.0 b/	6,100.0 b/
Aluminum exports..	308.6	286.8	292.2	328.3	323.4	503.6	580.7	580.7	580.7
Net change in stockpile and inventory	+192.1	-68.6	-316.0	+192.7	-19.8	-109.5	+276.6	--	--
Apparent consumption.....	2,152.6	3,989.8	4,562.3	4,169.0	4,738.3	4,989.5	4,550.6	9,405.8	22,459.8

a/ Secondary recovery assumed to equal 21 percent of supply in 1980 and 25 percent in 2000.

b/ Imports in 1980 assume one-quarter of increased consumption of primary aluminum over 1970 to be supplied from foreign reduction plants, and in 2000 one half of the increase over 1980.

Source: 1960, 1965-70 -- Aluminum Association, Annual Statistical Review, 1970; 1980 and 2000 -- RRNA probable projections.

Geographical Distribution of Reduction Capacity

At present the largest single concentration of reduction capacity, 35 percent of the U.S. total, is located in the Pacific Northwest (table 2) and is based principally on imported alumina from Australia and Surinam and on shipments of alumina from gulf coast ports. A considerable further expansion of capacity is expected in the Pacific Northwest because of the continued availability of relatively inexpensive power, although comparable increases in capacities should also take place in the Midwest and along the gulf coast. New capacity will also be available along the Atlantic coast based on supplies of alumina from Africa.

There appears to be potential power resources in all regions for these developments. However, most of the additional installations will be thermal. The advantages of hydropower in the Pacific Northwest will diminish and may to some extent give way to power generated from low-cost coal in some of the Mountain States. On balance, however, it is assumed that aluminum reduction capacity in 1980 and 2000 will be distributed regionally about as it was in 1970, with some shift away from the Pacific Northwest and Midwest.

Alumina Assumptions

1. Little or no new alumina capacity will be built in the United States.

2. All the major foreign sources of bauxite will install new or increased capacity for the production of alumina. Such capacity in traditional U.S. sources of bauxite will be built by U.S. companies and will be vertically integrated into their supply system.

3. U.S. imports of alumina will rise as required to fill the gap between indigenous production and the requirements of the aluminum plants.

4. Australia will be the largest single source of alumina, and Jamaica and Surinam will divert an

ever-increasing proportion of their bauxite production into alumina. In the late 1970's West Africa (Guinea and Ghana) will be a significant source and will, after Australia, become the second largest source by the end of the century.

5. Exports of alumina will decline to zero by 1980.

Bauxite Assumptions

1. Bauxite, and alumina derived from bauxite, will continue to be the principal raw materials for the production of aluminum, and their supplies will not be a limiting factor on growth. The large known U.S. reserves of clays containing aluminum, which are currently uneconomic but which could be utilized by present technology, will continue to be uneconomic.

2. Reserves of economic bauxite in the United States will be adequate to support present annual production of 1.6 million tons, yielding approximately 0.4 million tons of aluminum annually.

V. PROJECTIONS FOR 1980 AND 2000

Table 10 shows our projections of aluminum supply and demand in the United States for 1980 and 2000 compared with actual data for 1960 and 1965-70. The projections, which are based on previously discussed assumptions, are defined as our "probable" projections. Primary aluminum production, the determinant of aluminum raw materials requirements, increases at a much slower pace in these projections than does apparent consumption because of the assumed increases in the share of secondary recovery and aluminum imports in the total supply. Should these increases not be realized, indigenous production of primary aluminum would be proportionately greater, as would import requirements for aluminum raw materials.

Higher or lower rates of growth in aluminum consumption would have a similar effect. The implied growth rate in consumption from 1970 to 1980 in these projections is an average of 7.5 percent annually, and the rate from 1980 to 2000 is 4.5 percent. Aluminum consumption in 1970 was nearly 10 percent below 1969. The implied annual growth rate from 1969 to 1980 is 5.9 percent.

Table 11 shows import requirements for aluminum raw materials resulting from the primary aluminum production estimates, after account is taken of assumed indigenous bauxite production of 1.6 million tons with an aluminum content of 400,000 tons. The aluminum content of imported bauxite is assumed to peak at 3.5 million tons by 1980, compared with 3.3 million in 1970. This is consistent with the assumption that little or no additional alumina capacity will be built in the United States. The requirements for alumina imports

are the residual after the aluminum content of bauxite imports is deducted.

The aluminum content of alumina is converted to an alumina weight basis by multiplying by two. The dry weight equivalent of the aluminum content of bauxite imports is a multiple of four. The dry weight is then adjusted to an estimated shipping weight based on the average moisture content of U.S. imports of bauxite of 12.0 percent.

Under the assumptions employed, the shipping weight of bauxite imports shows an insignificant increase from 1970 to 2000, while the shipping weight of alumina imports increases from 2.6 million tons in 1970 to 5.7 in 1980 and 15.2 in 2000.

Table 11 also shows a high estimate. This estimate assumes that higher aluminum consumption requirements, lower secondary recovery, or lower imports of aluminum metal will cause U.S. aluminum production requirements to be 20 percent higher in 1980 and 30 percent higher in 2000 than in the probable estimates (table 10). It also assumes that alumina capacity will be expanded to 4.0 million tons in 1980 and 5.0 million tons in 2000, rather than remaining virtually stable as is assumed in the probable estimate. The effect of these alternative assumptions is to increase the total requirement for raw material imports and to increase the volume of bauxite imports from 15.9 million tons in the probable estimate to 18.2 million tons in 1980 and 22.7 million tons in 2000. Total raw material imports are 24.6 million tons in 1980 and 40.8 million tons in 2000.

No attempt is made to present a low estimate, since the probable estimate is considered to be on the conservative side. Quantitatively significant reductions in the raw material import requirements below the probable estimates would be difficult to support. Raw material import requirements could conceivably exceed the high estimate by a significant quantity, assuming that all or most of the variables affecting the demand for raw material imports are found to have been

Table 11. Imports of Bauxite and Alumina for Use in the Production of Alumina and Aluminum for 1970, 1980 and 2000 in Aluminum Content, Dry Weight and Shipping Weight

(In thousands of short tons)

Year	Alumina		Bauxite			Total		
	Aluminum content	Weight	Aluminum content	Dry weight a/	Shipping weight	Aluminum content	Dry weight	Shipping weight
1970..............	1,277.4	2,554.8	3,317.9	13,271.9	15,074.9 b/	4,595.3	15,772.7	17,629.7
Probable estimate								
1980............	2,856.5	5,713.0 c/	3,500.0	14,000.0	15,909.0	6,356.5	19,713.0	21,622.0
2000............	7,590.5	15,181.0 c/	3,500.0	14,000.0	15,909.0	11,090.5	29,181.0	31,090.0
High estimate								
1980............	3,227.8	6,455.6 c/	4,000.0 d/	16,000.0	18,181.8	7,227.8 e/	22,455.6	24,637.4
2000............	9,017.7	18,035.4 c/	5,000.0 d/	20,000.0	22,727.3	14,017.7 e/	38,035.4	40,762.7

a/ Shipping weight less 12.1 percent estimated moisture content.
b/ 93 percent of bauxite imports; other 7 percent not used for aluminum production.
c/ Alumina exports, which were 1,058,700 tons in 1970, assumed to be zero in 1980 and 2000.
d/ Assumes increase in U.S. alumina capacity to 4.0 million tons in 1980 and 5.0 million tons in 2000.
e/ Assumes aluminum production 20 percent above probable estimate in 1980 and 30 percent above in 2000.

Table 12. Estimated Imports of Bauxite and Alumina by Country of Origin, 1980 and 2000

(In millions of short tons)

Country	Probable		High	
	1980	2000	1980	2000
Bauxite				
Caribbean......	14.0	12.0	14.0	12.0
West Africa....	1.9	3.9	4.2	10.7
Total.........	15.9	15.9	18.2	22.7
Alumina				
Caribbean......	2.0	4.0	2.0	4.0
West Africa....	1.3	7.2	1.8	9.0
Australia......	2.4	4.0	2.7	5.0
Total.........	5.7	15.2	6.5	18.0

Table 13. Comparative Estimates of U.S. Aluminum Consumption

(In millions of short tons)

Estimates	1975	1980	1995	2000
RRNA:				
Probable...............	n.a.	9.4	n.a.	22.5
Stanford Research.......	Seven percent growth to 1975 and 6 to 7 percent thereafter.			
Booz-Allen:				
Low....................	n.a.	n.a.	n.a.	n.a.
Medium.................	n.a.	n.a.	17.8	n.a.
High...................	n.a.	n.a.	34.2	n.a.
Bureau of Mines:				
Low....................	n.a.	n.a.	n.a.	22.4
Medium.................	n.a.	n.a.	n.a.	33.4
High...................	n.a.	n.a.	n.a.	44.4
Litton Systems..........	n.a.	n.a.	n.a.	n.a.
RFF:				
Low....................	n.a.	3.4	n.a.	6.6
Medium.................	n.a.	5.7	n.a.	14.7
High...................	n.a.	10.1	n.a.	31.1

Source: Stanford Research Institute, Projections of Principal U.S. Dry Bulk Commodity Seaborne Imports and Exports for 1975 and 1995, prepared for U.S. Department of Commerce, Maritime Administration. Booz-Allen Applied Research, Inc., Forecast of U.S. Oceanborne Foreign Trade in Dry Bulk Commodities, prepared for U.S. Department of Commerce, Maritime Administration, March 1969. U.S. Department of Interior, Mineral Facts and Problems, Bureau of Mines Bulletin 650, 1970. Litton Systems, Inc., Oceanborne Shipping Demand and Technology Forecast, Part I, prepared for U.S. Department of Commerce, Maritime Administration, June 1968. Hans H. Landsberg, Leonard L. Fishman, and Joseph L. Fisher, Resources in America's Future: Pattern of Requirements and Availabilities, 1960-2000 (Baltimore: The Johns Hopkins Press for Resources for the Future, 1963).

Table 14. Apparent U.S. Consumption of Aluminum, 1969, 1970 and Estimated for 1980, 1995, and 2000, and Implied Annual Growth Rates

Year and source	Apparent U.S. consumption	Annual growth rates	
		1969	1970
	(mil. net tons)		
1969:			
Actual......	4.989		
1970:			
Actual......	4.550		
1980:			
RRNA........	9.4	5.9	7.5
RFF-high....	10.1	6.6	8.3
1995:			
Booz-Allen..	17.8	5.0	5.6
Booz-Allen..	34.2	7.7	8.4
2000:			
RRNA........	22.5	5.0	5.5
Bureau of Mines......	33.4	6.3	6.9
RFF-medium..	14.7	3.5	4.0
RFF-high....	31.1	6.1	6.6

Source: Tables 10 and 13.

annual growth rates in this and other studies of the subject. It will be observed that the probable projection of aluminum consumption for 1980 is very near the high estimate in the Resources for the Future (RFF) study, Resources in America's Future. None of the other studies had a specific estimate for 1980. For the year 2000 our estimate is approximately the same as the low projection by the Bureau of Mines in Mineral Facts and Problems, and is midway between the high and medium estimates by RFF.1/

Of the other studies considered, only that by Booz-Allen presents import estimates separately for aluminum and bauxite (table 15). However, these estimates are not integrated, and it is impossible to interpret or to relate the individual projections to an explicit set of assumptions.

The Stanford Research study similarly cannot be interpreted because bauxite and alumina are combined. The Litton Systems study projects only bauxite, employing essentially statistical extrapolation techniques related to bauxite imports to arrive at its estimates.

1/ A more recent study by RFF entitled Trends in the World Aluminum Industry (Baltimore: Johns Hopkins Press, 1967) has a highly sophisticated discussion of the conceptual and analytical problems inherent in the projection of aluminum consumption. For 1980, the report has an estimate of consumption for the United States and Canada combined of 9.3 million tons, compared with our estimate for the United States of 9.4 million.

Table 15. Comparative Estimates of U.S. Imports of Bauxite and Alumina

(In millions of short tons)

Estimates	1975	1980	1995	2000
RRNA				
Bauxite:				
Probable	n.a.	15.9	n.a.	15.9
High	n.a.	18.2	n.a.	22.7
Alumina:				
Probable	n.a.	5.7	n.a.	15.2
High	n.a.	6.5	n.a.	18.0
Stanford Research				
Bauxite and alumina	24.1	n.a.	52.7	n.a.
Booz-Allen				
Bauxite:				
Low	n.a.	8.0	8.0	n.a.
Medium	n.a.	10.5	10.1	n.a.
High	n.a.	15.6	17.6	n.a.
Alumina:				
Low	n.a.	1.2	1.2	n.a.
Medium	n.a.	8.6	18.7	n.a.
High	n.a.	17.3	61.7	n.a.
Bureau of Mines	n.a.	n.a.	n.a.	n.a.
Litton Systems				
Bauxite:				
Constant growth	n.a.	71.3	n.a.	774.3
Adjusted	n.a.	34.4	n.a.	77.8
RFF	n.a.	n.a.	n.a.	n.a.

Source: See table 13.

APPENDIX. FOREIGN BAUXITE AND ALUMINA OPERATIONS OF U.S. COMPANIES[1]

Australia

Kaiser owns 45 percent of Comalco Industries, which operates a 65,000 ton alumina plant at Bele Bay, and is planning what will be the world's largest alumina plant, with an ultimate capacity of 5 million tons per year, at Weija. Initial output scheduled for 1974 is 700,000 tons per year.

In addition, Kaiser owns 32 percent of Queensland Alumina, which operates an alumina plant approaching an output of 1,430,000 tons.

American Metals Climax owns 30 percent of Amax Bauxite Corporation, which is proceeding with a project at Port Warrander to produce 1.34 million long tons per year of alumina by 1974.

Alcoa owns 51 percent of Alcoa of Australia, which is expanding alumina output at Kwinana in western Australia to 1.37 million tons per year and is planning to build a second alumina plant with a capacity of 550,000 tons per year at Pinjarra.

1/ Data taken from U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, 1969, pp. 207-210, and telephone conversation with Horace Kuntz of the Bureau of Mines.

Brazil

Alcoa owns 50 percent of Alcomina, which operates an alumina plant.

Colombia

Kaiser has filed an application for a bauxite mining firm with the Colombian Government.

Dominican Republic

Alcoa produces bauxite.

French Guiana

Alcoa is in a joint venture with Pechiney to mine up to 1 million tons of bauxite, which would be shipped by barge to the alumina plant of Surinam Aluminum Company, an Alcoa subsidiary.

Haiti

Reynolds Metals owns Reynolds Haitian Mines, which produces bauxite.

Jamaica

Alumina Partners of Jamaica (ALPART) is owned jointly by Anaconda, Kaiser, and Reynolds. The company produces bauxite and processes it into alumina at a plant with a capacity of 950,000 short tons annually, and has an additional 350,000 tons of capacity under construction.

Revere Copper and Brass owns Revere Jamaica Alumina Limited, which in 1969 announced plans for the construction of an alumina plant with an initial capacity of 220,000 tons per year.

Alcoa owns Alcoa Minerals of Jamaica, which produces bauxite and plans to start operation of an alumina plant in 1971 with an initial capacity of 880,000 short tons of alumina.

Surinam

Alcoa produces bauxite and alumina.

Guyana

Reynolds produces bauxite.

Ghana

Kaiser is engaged in exploratory drilling for bauxite with the prospect for an alumina plant to be constructed if and when adequate reserves can be determined. The alumina would go to the Tema Primary Aluminum Plant operated by Valco, 90 percent of which is owned by Kaiser and 10 percent by Reynolds.

Guinea

The Republic of Guinea owns 51 percent of Halco Mining, with the other 49 percent held by Alcan, Alcoa, and Harvey, and by German, French, and Italian aluminum companies. Halco will annually produce from 8 to 9 million tons of bauxite, which will be delivered to Halco's aluminum company associates in proportion to their investment in the company.

Olin-Mathieson owns the FRIA alumina plant.

Indonesia

Alcoa has an exploration contract for bauxite with the Indonesian Government which, if successful, would result in the development of mines and alumina refineries.

Germany

Reynolds owns a new 770,000 ton alumina plant in partnership with Vereinigte Aluminum-coke.

ANNEX A-5. U.S. COAL EXPORTS

CONTENTS

INTRODUCTION

This study deals with bituminous coal only, since present and prospective exports of anthracite are not of a volume to require deep-draft vessels. It does not include exports to Canada, which move by rail and through the Great Lakes. It deals separately with two distinct foreign end-use markets for bituminous coal, i.e., the manufacture of coke for metallurgical and other uses (coking coal) and the generation of electric power (steam coal). Other markets are understood to be insignificant.

The steam coal market has declined sharply in recent years to a level of about 5 million tons, almost all of which is purchased by West Germany. In the meantime, overseas exports of coal for metallurgical use tripled in the last 10 years, reaching a level of 46.7 million short tons in 1970, and accounting for approximately 90 percent of total overseas bituminous coal exports (see table 1 and appendix table 1). However, 1970 was an abnormally high year for overseas metallurgical coal exports, the increase over 1969 being 11.5 million tons, or nearly one-third. Exports thus far in 1971 are substantially below the same period of 1970.

Primary emphasis in this study of future U.S. coal exports is devoted to the export of coal for metallurgical uses. The competitive position of the United States as a source of metallurgical coal to foreign countries is much stronger than its position as a supplier of steam coal primarily for the generation of electrical energy. This is because other forms of energy can be used to substitute for metallurgical fuels in the production of pig iron to a very limited

Table 1. U.S. Overseas Exports of Bituminous Coal

(Thousands of short tons)

Year	Metallurgical	Other	Total	Metallurgical as percent of total
1961......	15,778	7,962	23,740	66.5
1962......	18,103	8,834	26,937	67.2
1963......	21,525	11,733	33,258	64.7
1964......	23,151	10,572	33,723	68.7
1965......	25,936	8,519	34,455	75.3
1966......	25,422	7,993	33,415	76.1
1967......	27,462	6,709	34,171	80.4
1968......	29,195	4,615	33,810	86.4
1969......	35,217	4,109	39,326	89.6
1970......	46,695	5,363	52,058	89.7

Source: Appendix table 1.

extent, and because the U.S. resources of metallurgical coal are among the most plentiful, the highest quality, and the most economic in the free world. On the other hand, U.S. coal for steam-raising purposes must compete in foreign markets, not only with indigenous steam coal resources, which are more plentiful than metallurgical coal resources, but also with such freely substitutable alternatives as natural gas, fuel oil and nuclear energy.

These basic conditions undoubtedly explain the substantial differences referred to earlier in the U.S. export trends for these two classes of coal. From appendix table 1, it is apparent that throughout the last 10-year period overseas markets for coal for other than metallurgical use have been concentrated principally in Western Europe, with shipments to other destinations being insignificant. Since 1961 the market has not only declined substantially, but has also narrowed considerably, so that by 1970, nearly 90 percent of such exports were to West Germany, and no other country in Europe or elsewhere took as much as 300,000 tons. Belgium, France, Italy and the Netherlands were substantial importers of nonmetallurgical coal from the United States during the early part of the decade, but these imports were curtailed sharply following the peak years of 1963 and 1964.

Insight into the problems of marketing U.S. coal for steam-raising purposes, and of estimating future demands for U.S. coal in these markets, is gained from a recent report of the Commission of the European Communities.1/ This study shows that the Community demand for coal for all purposes declined from 290.6 million metric tons in 1957 to 211.9 million metric tons in 1969. While the total consumption of coal for the generation of electric power has been increasing, preference has been given to indigenous coal over imported coal through the restriction of imports from

1/ Commission of the European Communities, An Examination of the Question of Coal Supply and Production in the Community, Document 3541/1/XVII/70-E.

non-Community sources and through direct financial subsidies. Thus for 1969 of a total consumption for power generation of 66.8 million tons, only 7.8 million tons were imported.1/

Exporters other than the United States, particularly Poland and the U.S.S.R., have increased their share of the Community market substantially during the past 10 years. Thus in 1959 the United States supplied approximately 73 percent of total Community coal imports of 19.2 million metric tons, compared with 53 percent of total imports of 20.9 million tons in 1968.2/

The effect of coal import restrictions and subsidization of indigenous coal on consumption by the power industry is revealed in the relationship between the generation of electric power from imported coal and from petroleum products. In 1968, of a total power generation from all sources of 492.7 billion kwh, 201.0 billion kwh, or 41 percent, was generated from indigenous hard and brown coal; 22.3 billion, or less than 5 percent, from imported coal; and 96.9 billion, or nearly 25 percent, from imported petroleum products.

For 1975 the study projects total generation of 850 billion kwh. While generation from indigenous hard coal will decline in absolute terms, and the share of indigenous energy sources including natural gas and nuclear energy will decline from 75.2 percent in 1968 to 55.3 percent in 1975, the generation from imported hard coal and petroleum will increase from 119.2 billion to 376.6 billion kwh.3/ This is the equivalent of 117.0 million metric tons of coal in 1975, and an increase of 79 million metric tons over consumption of imported coal and petroleum products in 1968.

However, the report observes that:

1/ Ibid., Annex 5, paragraph 29, page 19, and paragraph 56, page 34.
2/ Ibid., Annex 7.
3/ Ibid., Annex 4.

> ...there are so many question marks about the supply position that it is impossible to estimate what share of the 80 million ton margin will fall to fuel oil and what share to imported coal. The 1975 figures for coal in Annex 5 have been left incomplete because it cannot be calculated what part imported coal will play in the power station sector. If it is assumed that imported power station coal competing against fuel oil secures at most a quarter of the margin to be made good, total Community imports of non-Community coal in 1975...

for power stations would range from the 7 million ton 1968 level to a possible high of 27 million tons.1/

Imports of steam coal for industry generally are estimated in the same source for 1975 at an inconsequential 1 to 2 million tons.

The report observes that due to increasing internal U.S. demand there is not much unutilized coal production capacity. Therefore, additions to capacity would be required for increased exports of steam coal. Such capital projects would not be undertaken except under long-term contracts.

> There is no telling to what extent the Community electricity industry would be prepared, on the strength of its assessment of the future relative competitive positions of imported coal and hydrocarbons, to conclude such contracts, nor whether coal producers outside the Community would attempt to step up their disposals of power station coal to the Community without pretty full guarantees of purchase.2/

1/ Ibid., pp. 21 and 22.
2/ Ibid., pp. 33 and 34.

It is further observed that it would be pointless for non-Community producers to even try to acquire substantial shares in this market for power station coal unless the import restrictions in some Community countries were lifted.

In choosing between imported coal and fuel oil, an electrical utility may be expected to place primary emphasis on relative price. The preponderance of imported fuel oil over imported coal as a source of fuel for the Community electricity industry is undoubtedly due to the fact that fuel oil has had a competitive edge over some or most imported coal. In looking at the possible future consumption of imported coal from the United States for power generation in the Community and elsewhere, one must make an assumption about the future competitive relationship of these principal fuel sources.

Unfortunately, both the cost and prices of U.S. coal and of crude petroleum and petroleum products from foreign sources have been subject to a very dynamic upward tendency during the past year or two. For the U.S. coal industry, tight market conditions and increasing costs of production resulted in sharp increases in coal prices. As an example, the BLS Wholesale Price Index for coal rose from an annual average of 112.5 in 1969 to 150.0 in 1970, and was 182.9 in August 1971.1/

Production cost increases are understood to result primarily from increases in wage costs, in capital costs for the development of new mines, and declining labor productivity resulting from enforcement of the new Coal Mine Safety Act. Thus, there are fundamental forces at work in the U.S. coal industry in the direction of higher coal costs and prices. These would, however, apply more to deep mine underground coal, the principal source of metallurgical coal, than to surface or strip mine coal, a principal source of steam coal for power generation. However, both will be significantly

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1/ U.S. Department of Commerce, Bureau of Labor Statistics, Survey of Current Business, September 1971.

affected by the provisions of the new contract arrangements between the United Mine Workers and the coal producers for increased wage levels and fringe benefits for coal miners.

To the extent that these cost and price increases apply to the export of steam coal, and there is no reason why they should not, they have an adverse effect on the competitive relationship of that coal to other coal imports in Europe and to residual fuel oil.

On the other hand the agreement signed early in 1971 between the international oil companies and the Organization of Petroleum Exporting Countries resulted in substantially increased posted prices for Middle East crude oil. This increase in posted prices, plus the impact on tanker rates of a shortage of tankers, resulted in very sharp increases in refinery prices for heavy fuel oils in Europe. Between November 1969 and March 1971 refinery prices (including taxes) per metric ton for heavy fuel oils rose from $20.30 to $28.70 in Hamburg, from $12.90 to $24.10 in Rotterdam, from $13.50 to $24.50 in Antwerp, from $13.00 to $21.50 in Le Havre, and from $19.50 to $23.20 in Milan.1/

During the period from November 1966 to January 1969, fuel oil prices in Europe tended to decline in different markets by anywhere from approximately 10 to 20 percent.2/

In November 1968 heavy fuel oil refinery prices in Hamburg, Germany, were reported at $17.00 to $18.00 per ton. For 1968 the delivered price of U.S. coal in Germany, most of which goes to Hamburg, was reported

1/ Commission of the European Communities, The Situation of the Community Energy Market, Annex, Document X/375/71-E, April 1971.
2/ Commission des Communautes Europeenes, La Conjuncture Energetique dans la Communaute -- Situation 1969 - Perspectives 1970 (Brussels, 1970), tableau 22.

at $14.44 per ton.[1] Since virtually all coal imported into Germany from the United States is steam coal, these fuel oil and coal prices permit a comparison of the two energy sources in terms of fuel value in 1968. At 42 million B.t.u.'s per metric ton, the refinery price per metric ton of heavy fuel oil in Hamburg of from $17.00 to $18.00 would be equivalent to approximately 41 cents to 43 cents per million B.t.u.'s. If we assume a fuel value of 28.6 million B.t.u.'s per metric ton of U.S. coal, the cost per million B.t.u.'s of coal at $14.44 per ton is approximately 50 cents. Differences in handling costs, storage costs, and transport costs from refinery and port to point of consumption could have the effect of either broadening or narrowing this gap, but the figures do suggest that heavy fuel oil had a very strong competitive advantage over imported coal.

The March 1971 heavy fuel oil price at Hamburg of $28.70 per ton was the equivalent of approximately 68 cents per million B.t.u.'s, substantially above the 1968 imported coal price.

While data are not available on the trend in the delivered cost of U.S. coal in Hamburg since 1968, U.S. Bureau of the Census data show that the average value per short ton of bituminous coal exports to West Germany, f.o.b. port of shipment, increased from $9.74 in December 1968 to $14.11 in December 1970, an increase of $4.37. At 26 million B.t.u.'s per short ton, this is equivalent to approximately 17 cents per million B.t.u.'s. Total delivered costs in December 1970 were approximately 67 cents per million B.t.u.'s, very close to the equivalent heavy fuel oil price in March 1971. According to the same Bureau of the Census source, the average cost declined to $13.71 in May 1971, or about 1.5 cents per million B.t.u.'s.[2] However, heavy fuel oil prices also declined, reflecting a decline in tanker rates from 1970 peaks.

1/ Statistical Office of the European Communities, _Energy Statistics_, 1958-68, p. 101.
2/ Calculated from data in U.S. Department of Commerce, Bureau of the Census, _U.S. Exports Commodity by Commodity by Country_, FT410, December 1968, 1969, 1970, and May 1971.

One cannot reliably project for the next 10 to 20 years the competitive relationship between delivered U.S. steam coal and delivered residual fuel oil in major markets in Europe or in other foreign markets. Both the international petroleum and the U.S. coal industries have lost a certain degree of control over cost and prices due to the operation of political forces, e.g., the assertion of strong bargaining power by the petroleum exporting countries over royalties and taxes on exported crude petroleum, and the impact of the Coal Mine Safety legislation on coal production costs in the United States. On balance, however, it would appear that the opportunities for price flexibility are somewhat greater for residual fuel oil than for U.S. coal. Unlike the coal industry, the petroleum refining industry has a product mix ranging from very high value products such as aviation and other motor fuel down to residual fuel oil, the latter constituting the marginal share of output. Refineries can be expected to price their residual output at a level that will permit it to be absorbed in the market and to compensate for the loss of revenues by increasing the price for other refinery products.

On the other hand the coal mines, from which significant long-term increments in steam coal exports would come, would more and more tend to be single-product, single-market producers, with production dedicated under long-term contract. Under these conditions the delivered cost of U.S. steam coal must cover the full economic cost of production and transport, including a competitive return on invested capital, or, as the Commission of the European Communities observed, the coal will not be produced for export.

Thus, the outlook would appear to be for no significant reversal of the competitive relations between U.S. steam coal and residual fuel oil that have applied in the past. If this assumption should prove valid, there would not appear to be a basis for the projection of any significant growth in the European market for U.S. steam coal, or in any of the other markets which presently rely on fuel oil for the bulk of their electrical power generation.

In this study, therefore, we are not projecting specific U.S. exports by country of destination of steam coal, since it is assumed that the quantities involved will not be significant from the point of view of ocean transportation and port facility requirements.

I. METALLURGICAL COAL

Introduction

The primary purpose of this study is to derive forecasts of U.S. overseas exports of coal for metallurgical use for the years 1980 and 2000. While the forecasts include all countries presently or prospectively importing at least 1 million tons of metallurgical coal from the United States by sea, the focus is primarily on the European members of the Organization for Economic Cooperation and Development (OECD) and on Japan.

Despite the substitution of noncoking coal and other fuels for metallurgical coal, and the replacement of the blast furnace by methods of reducing iron ore to pig iron without any coke at all, Western Europe is expected to turn to the United States for coking coal on a very large scale in this and the following decades. Japan, which is the major customer today, buying over half of U.S. exports of coal for metallurgical use in 1970, will diversify its sources of supply and should import less, relatively and absolutely, as early as 1980.

Coal for metallurgical use links coal mining with an industry that is one of the cornerstones of an industrially advanced economy: the iron and steel industry. The prospects of coal for metallurgical use will be affected by the demand for iron and steel, and by all the manifold technical changes sweeping over that industry today and in years ahead.

Review of Present Origins and Destinations of U.S. Coking Coal Exports

Exporting Districts

As table 2 shows, most overseas coal exports (90 percent in 1970) originate in Districts 7 and 8, composed mainly of the states of Virginia and West Virginia. Hence these two districts are also the principal origins of U.S. coking coal exports. (See figure 1 for map of U.S. coal-producing districts and tables 3 and 4 for locational characteristics of metallurgical coal production and reserves.)

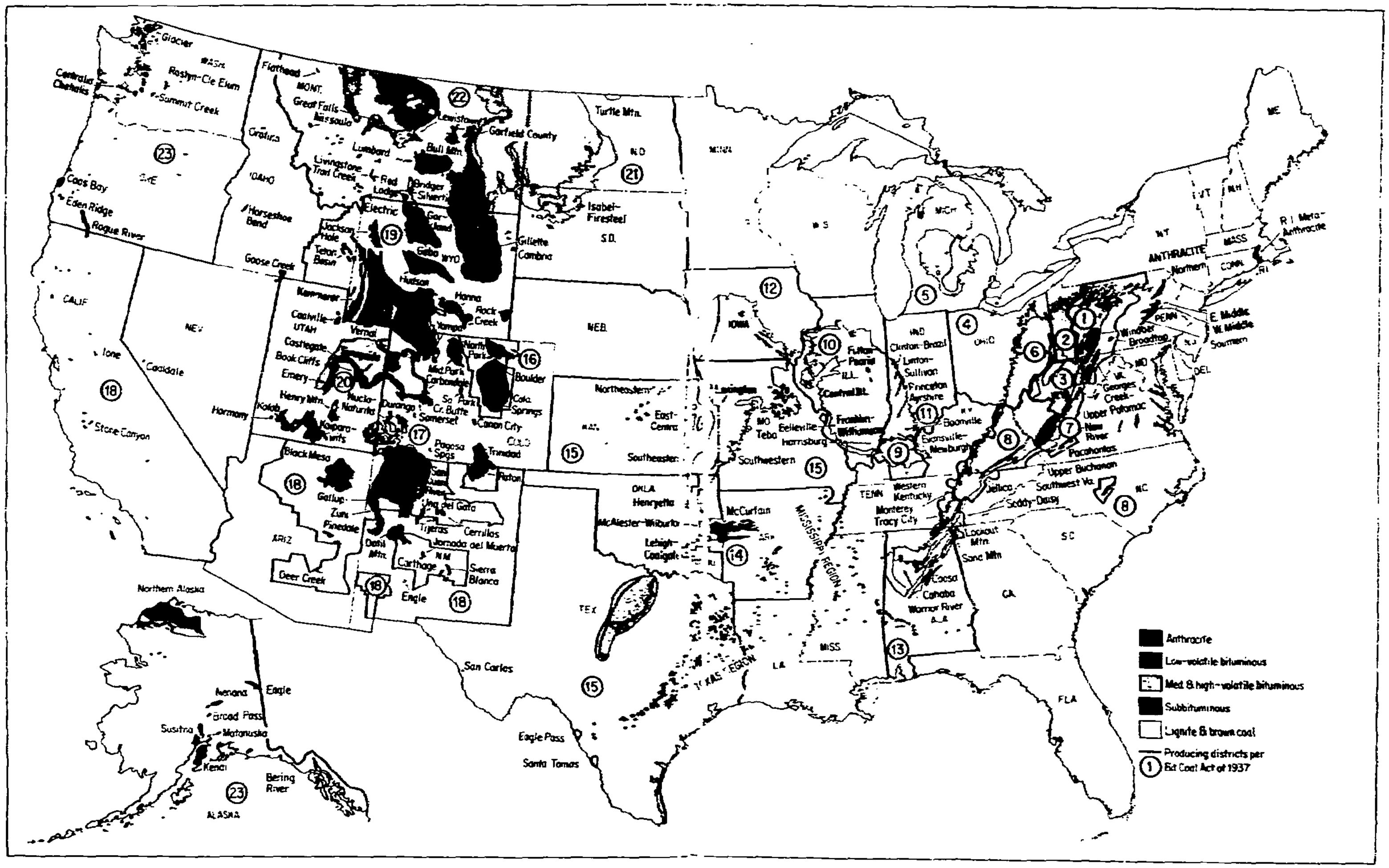
District 7, the source of most low-volatile coking coals, comprises areas of southern Virginia and southern West Virginia. District 8, the source of most high-volatile coking coals, comprises areas in southern Virginia, southern West Virginia, eastern Kentucky and eastern Tennessee.

Coking coals from Alabama, Arkansas and Oklahoma may increasingly enter international trade. But these sources are not expected to significantly alter the existing pattern of supply because of reserve limitations and qualitative and cost disadvantages.

The emergence of Arkansas and Alabama as potential continuing sources of coking coal for export overseas is a recent development. As shown in table 2, exports originating in Arkansas and Oklahoma commenced in 1969, and exports originating in Alabama, Georgia, and Tennessee commenced in 1970. Arkansas coal is shipped under a long-term contract with Japanese trading firms providing for a maximum quantity of 1 million tons annually over 12 years starting in 1968.1/ The coal is low volatile and low sulfur, and is roughly comparable with low-volatile coals from District 7. However, resources of

1/ The Japan Commerce, Ltd., The Japan Commerce Daily (Iron and Steel), Tokyo, Japan.

FIGURE 1. MAP OF THE COAL FIELDS OF THE UNITED STATES



Source: 1971 Keystone Coal Industry Manual (New York: McGraw-Hill, Inc., Mining Informational Services, 1971), p. 392.

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Table 2. Origin Districts of U.S. Overseas Exports of Bituminous Coal, 1960, 1969 and 1970

(Thousands of short tons)

District	1960	1969	1970
1 (Eastern Pennsylvania).........	1,081	1,404	2,709
3 and 6 (Northern West Virginia).	544	1,131	2,275
7 (Virginia, West Virginia)......	10,556	15,580	17,430
8 (Virginia, West Virginia)......	12,499	21,096	28,901
13 (Alabama, Georgia, Tennessee).	91	--	a/
14 (Arkansas, Oklahoma)..........	--	74	190
20 (Utah)........................	47	76	260
17 (Southern Colorado)...........	--	--	a/
Total............................	24,818	39,361	51,766 a/

a/ Exports from Districts 13 and 17 not shown to avoid disclosure, and are not included in total. Exports from both districts are estimated at 292,000 tons, the difference between the total of the districts for which data are shown and the total overseas exports given in appendix table 1.

Source: U.S. Department of the Interior, Bureau of Mines, Bituminous Coal and Lignite Distribution, Calendar Years 1960, 1969, 1970.

Table 3. Production of Metallurgical Grade Coals in the United States in 1968 According to Volatile-Matter Content by Region and State

(In thousands of short tons)

Region and State	Metallurgical grade[a/]			
	High volatile	Medium volatile	Low volatile	Total
Appalachian states				
Alabama.........	2,536	1,346	--	3,882
Kentucky........	48,365	--	--	48,365
Pennsylvania....	1,198	3,139	981	5,318
Tennessee.......	3,879	--	--	3,879
Virginia........	18,129	10,951	5,721	34,801
West Virginia...	54,462	11,166	31,767	97,395
Subtotal......	128,569	26,602	38,469	193,640
Midwestern states				
Arkansas........	--	--	211	211
Illinois........	5,000	--	--	5,000
Oklahoma........	--	336	--	336
Subtotal......	5,000	336	211	5,547
Western states				
Colorado........	513	702	--	1,215
New Mexico......	--	--	--	--
Utah............	3,762	--	--	3,762
Subtotal......	4,275	702	--	4,977
Total.............	137,844	27,640	38,680	204,164

a/ Coking coal containing not more than 8.0 percent ash and 1.25 percent sulfur.

Source: U.S. Department of the Interior, Coal for Coke Production, prepared for the Bureau of Mines by Eugene T. Sheridan and Joseph A. De Carlo, March 1971.

Table 4. Estimated Remaining Reserves of Coking Coal in the United States by Grade and Volatile-Matter Content on January 1, 1969

(Millions of short tons)

State	Metallurgical grade		
	High volatile	Medium volatile	Low volatile
Appalachian states			
Alabama...........	2,068.6	147.2	--
Eastern Kentucky..	20,016.9	--	--
Maryland..........	--	--	4.2
Ohio..............	1,245.7	--	--
Pennsylvania......	2,338.3	1,610.6	1,260.4
Tennessee.........	551.3	67.0	--
Virginia..........	3,360.0	3,687.8	795.3
West Virginia.....	34,924.9	10,491.6	11,133.7
Subtotal.........	64,505.7	16,004.2	13,193.6
Midwestern states			
Arkansas..........	--	--	1,182.5
Illinois..........	940.0	--	--
Indiana...........	--	--	--
Oklahoma..........	659.8	304.0	589.2
Subtotal.........	1,599.8	304.0	1,771.7
Western states			
Colorado..........	1,857.5	386.8	--
New Mexico........	--	--	--
Utah..............	1,298.2	--	--
Washington........	130.5	55.2	65.3
Subtotal.........	3,286.2	442.0	65.3
Total................	69,391.7	16,750.2	15,030.6

Source: U.S. Department of the Interior, Coal for Coke Production, prepared for the Bureau of Mines by Eugene T. Sheridan and Joseph A. DeCarlo, March 1971.

coal of this quality in Arkansas and Oklahoma are extremely limited and uneconomic to produce, and so far as is known the contract referred to is the only one in existence or under consideration. The U.S. supplier has experienced operational difficulties which have limited the delivery of coal under the contract, with shipments in 1970 amounting to 230,000 tons.1/

Export shipments from Alabama during 1970 went mainly to Japan and to several European countries (Belgium, West Germany, Spain). In addition, there are unconfirmed reports of long-term supply contracts having been negotiated with Alabama suppliers by Japanese trading and steel firms. One contract is reported to provide for maximum annual shipments of 670,000 tons, and the other, for 700,000 tons.2/

In anticipation of a long-term export market for coal from Alabama and neighboring states, the legislature of the State of Alabama is reported to have approved a bond issue for the financing of the construction of a new coal-loading station in the port of Mobile. The port is linked to the coal-producing fields in Alabama by the Alabama and Tombigbee Rivers, and the proposed waterway linking the Tombigbee with the Tennessee River would provide inland waterway access to coal fields in Tennessee and Kentucky.3/

Exporting Ports

Data are available on U.S. exports of bituminous coal by port, but not separately for coal for metallurgical uses. Table 5 shows these data for the principal ports of exit for overseas exports for the years 1968-70 and January-June 1971. The preponderance of the Appalachian region as the source for overseas export

1/ Ibid.
2/ By telephone from Mr. Liamari, U.S. Department of the Interior, Bureau of Mines.
3/ The Washington Post, June 10, 1971, pp. G1 and G3; and the Journal of Commerce, October 8, 1971.

Table 5. U.S. Exports of Bituminous Coal by Port, 1968, 1969, and January to June 1971

(Thousands of short tons)

Port	1968	1969	1970	Jan.-June 1971
Philadelphia..........	295.4	377.5	297.4	65.7
Baltimore.............	2,441.6	2,658.7	4,722.9	2,020.6
Norfolk...............	24,409.8	27,669.3	46,221.7	20,115.1
Newport News..........	7,522.9	9,374.7		
Mobile................	1.6	0.6	342.3	331.2
New Orleans...........	30.5	81.5	460.1	306.8
Port Arthur...........	--	0.1	15.9	65.7
Laredo................	--	--	107.7	87.6
Los Angeles...........	0.1	46.2	261.7	267.7
Long Beach............	7.6	48.2		
All other overseas....	10.7	13.9	140.6	74.4
Subtotal...........	34,720.2	40,270.7	52,560.3	23,334.8
Lake Ports............	15,991.1	15,997.0	18,347.9	6,300.7
Total..............	50,711.3	56,267.7	70,908.2	29,635.5

Source: 1968 and 1969 -- special tabulation by RRNA of data in U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division, Extracts from SA705 U.S. Exports; 1970 and 1971 -- U.S. Department of the Interior, Bureau of Mines, U.S. bituminous coal exports by Customs District, International Coal Trade, February and August 1971.

coal as shown in table 2 is reflected in the ports of exit, and the preponderance of Norfolk and Newport News within the group of Atlantic ports reflects the dominant positions of Districts 7 and 8 as sources of export coal within the Appalachian region. In 1969, for example, less than 200,000 tons of overseas coal exports moved through ports other than the Atlantic ports, and Norfolk and Newport News handled 93 percent of all overseas coal exports.

In 1970 and 1971, the emergence of Alabama, Arkansas, Colorado, and Utah as sources of coal exports is reflected in the movements through Texas ports and the ports of Mobile, New Orleans, and Los Angeles-Long Beach. But these movements are all relatively small, none achieving annual rates of 1 million tons in the first 6 months of 1971. Some of the increased movement through New Orleans is understood to have originated in the Appalachian area and moved to port by the Ohio and Mississippi river inland waterway system. However, these amounts, and the distribution of Arkansas coal exports among Louisiana and Texas ports, are not known.

In the Appalachian region, coal originating in Districts 1, 2, and 3 (Pennsylvania and northern West Virginia) moves principally through the ports of Baltimore and Philadelphia, and coal originating in Districts 7 and 8 moves through the ports of Newport News and Norfolk.

Ports of exit for U.S. overseas bituminous coal exports have largely been determined by relative distance from point of origin, and by the route and port facility characteristics of the railroads serving the individual mines originating export coal. Very few of the mines producing coal for export in the Appalachian area are served by more than one railroad. In 1965, 95 percent of total U.S. overseas exports of coal originated in mines served by the Norfolk and Western (N&W), Chesapeake and Ohio (C&O), Baltimore and Ohio (B&O), and Western Maryland Railroads. The percentage distribution was as follows:

Railroad	Percent
N&W	60.9
C&O	27.2
B&O	5.5
Western Maryland	1.7
Total	95.3

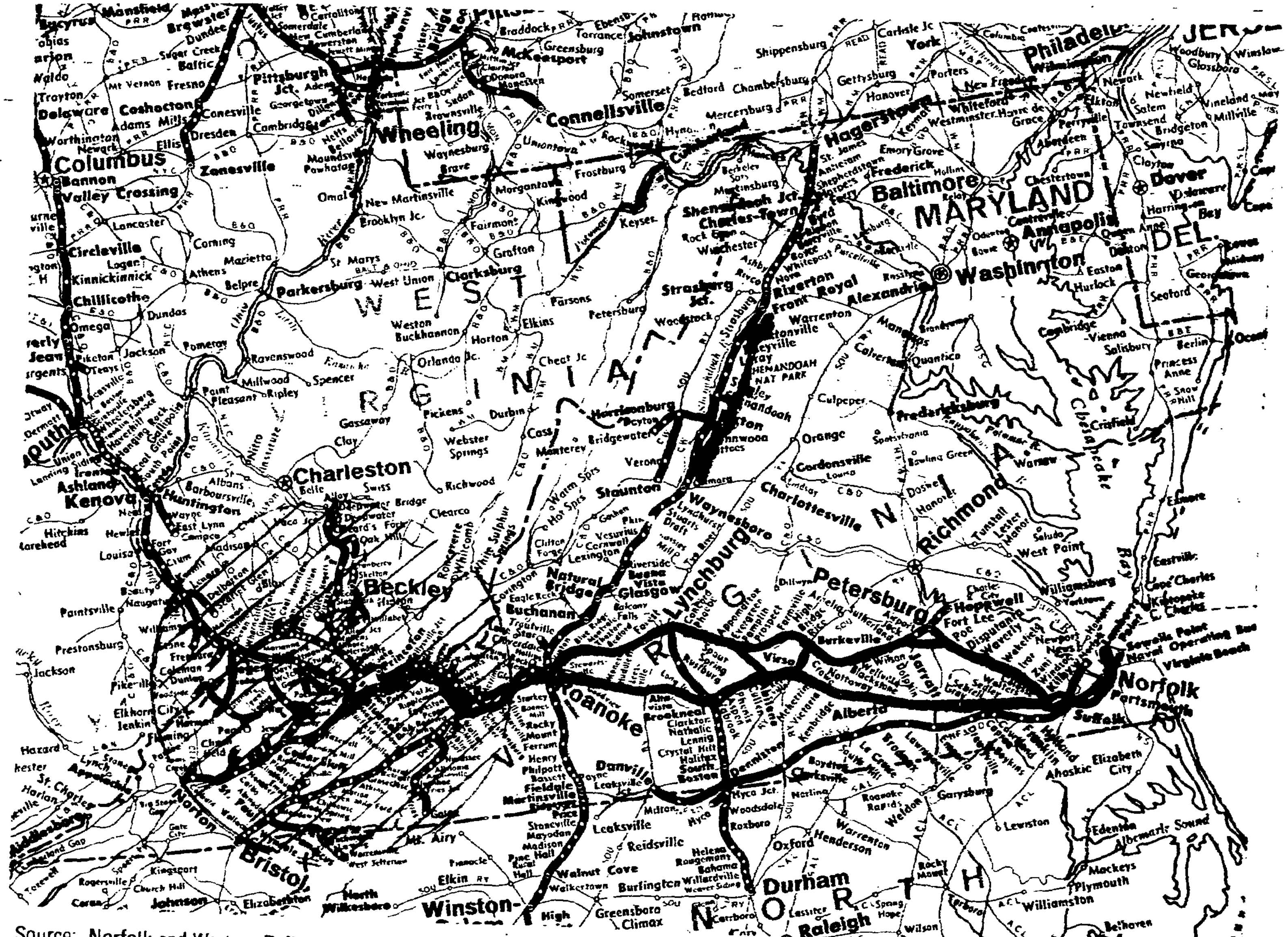
These same railroads served the mines and producing areas in the northeast quadrant (which includes Districts 1, 2, 3, 7 and 8), where 92.3 percent of the estimated U.S. low-volatile metallurgical coal reserves are located. Reserves in the areas served by the N&W and C&O account for 93 percent of the reserves in the areas served by all four railroads.

N&W and C&O railroads own and operate coal-loading facilities in the Hampton Roads ports of Norfolk and Newport News. They are the only railroads operating coal-loading facilities in that port area, and they operate no other coal-loading facilities on the Atlantic coast. Norfolk and Newport News are the closest ports to the export coal-producing areas in Districts 7 and 8.

The B&O owns and operates a coal-loading facility in Baltimore, and the Penn Central owns facilities in Baltimore and Philadelphia. The coal-producing regions served by these railroads are mainly in the northern portions of Districts 7 and 8 and Districts 1, 2, and 3, in which a relatively small proportion of overseas coal exports originates, and where a relatively small proportion of low-volatile metallurgical coal reserves is located. These areas are more favorably located geographically to the port of Baltimore (see figures 2 and 3).1/

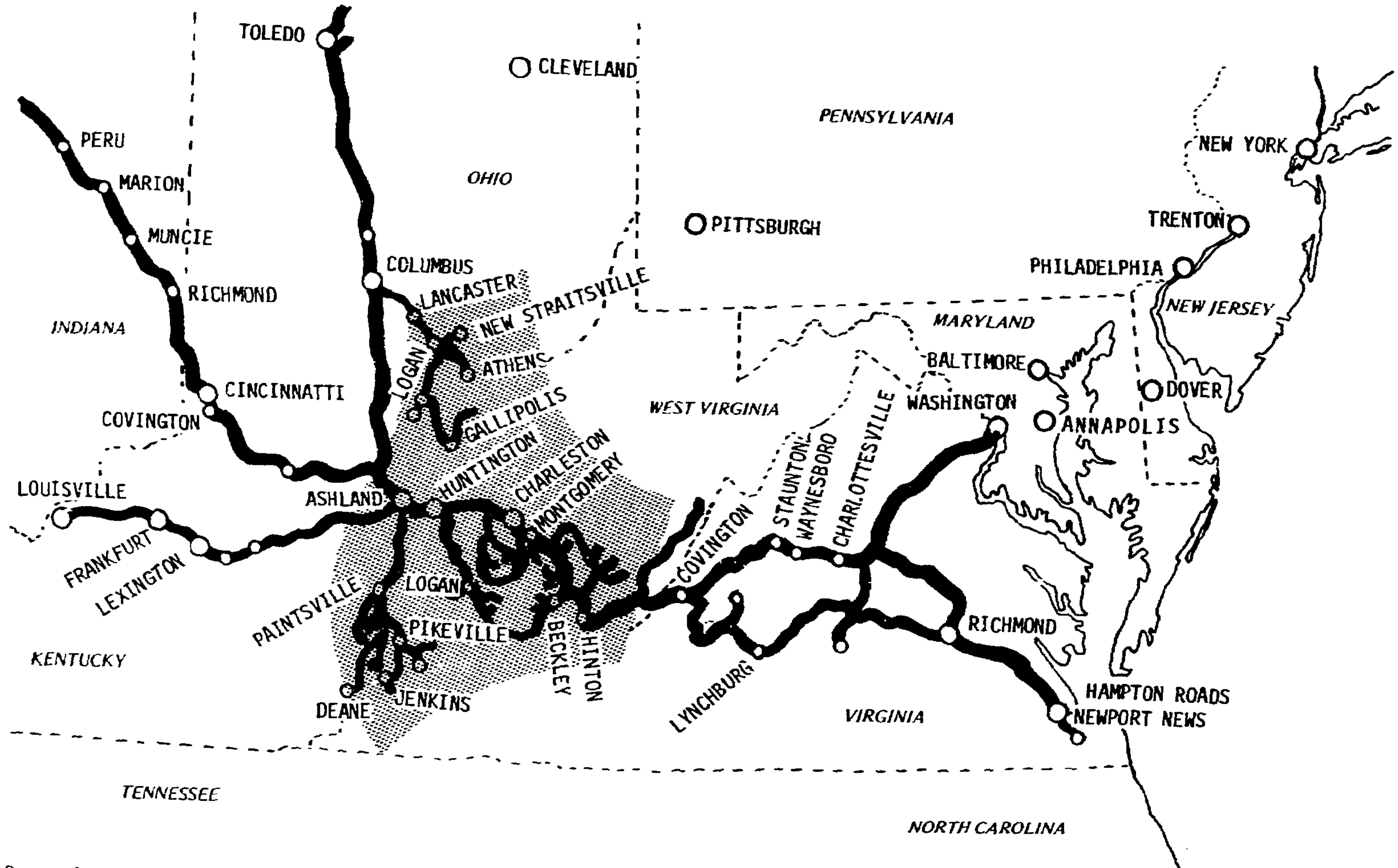
Since coal exported for metallurgical use in recent years has approximated 90 percent of total overseas

1/ Data on railroad originations of export coal and service to coal-producing areas from "Statement of Robert R. Nathan" finance Docket No. 23832 et al., before the Interstate Commerce Commission.



Source: Norfolk and Western Railway.

FIGURE 2. EXPORT COAL-PRODUCING DISTRICTS SERVED BY THE NORFOLK AND WESTERN RAILWAY



Source: Chesapeake & Ohio Railway.

FIGURE 3. EXPORT COAL-PRODUCING DISTRICTS SERVED BY THE CHESAPEAKE AND OHIO RAILWAY

exports, and since the Hampton Roads ports of Norfolk and Newport News have accounted for more than 90 percent of total overseas exports of all coal, the absence of specific data by port on exports of metallurgical coal does not pose a serious problem for this study. However, we made two independent estimates of such exports by major port areas. The first relied on cross analysis of the data on total U.S. exports of coal for metallurgical and nonmetallurgical uses by country of destination and data on exports of coal from Hampton Roads by country of destination.1/

In 1968, the United States exported 29.2 million tons of metallurgical coal overseas. On the basis of this analysis, we estimate that about 27.5 million tons left Hampton Roads in 1968, or about 94 percent. Only Baltimore, among the remaining ports, exported bituminous coal in any appreciable amount. To it, then, is attributed the remaining 6 percent of coking coal exports.

Another estimate of this same distribution, which is not so dependent on a single year, can be derived from table 6. Presently, at least 95 percent of coal exports to Europe leave from Hampton Roads. Similarly, at least 90 percent of exports to Japan leave from Hampton Roads. It is assumed that South America imports 100 percent from Hampton Roads. The total share of U.S. overseas exports of bituminous coal for metallurgical use to Europe (zones 5 to 8) is 34.4 percent, to Japan 58.4 percent, and to South America 7.2 percent (based on the 1968-70 average). The Hampton Roads' share of overseas metallurgical coal exports is 92.5 percent, if one assumes the same proportion for metallurgical coal as for all coal. The balance would be divided between Baltimore, ard gulf and West coast ports.

Zones of Destination

Table 4 shows U.S. average 1968-70 bituminous coal exports for metallurgical use to South America,

1/ Appendix table 1 and Record of Public Hearing,

Table 6. U.S. Overseas Exports of Bituminous Coal for Metallurgical Use to All Countries with Present or Prospective Volumes of at Least One Million Tons Annually, 1968-70 Average

(Thousands of short tons)

Country	Exports	
	Average	Percent
South America		
Zone 3:		
Chile...........................	248	.7
Zone 4:		
Argentina, Brazil..............	2,388	6.5
OECD Europe		
Zone 5:		
Austria, Belgium, Denmark, Finland, France (Atlantic region), West Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Spain (Atlantic region), Sweden, Switzerland, United Kingdom....	8,242	22.3
Zone 6:		
France (Mediterranean region), Italy, Spain (Mediterranean region)........................	4,022	10.9
Zone 7:		
Greece, Turkey.................	n.a.	n.a.
Other Europe		
Zone 7:		
Yugoslavia.....................	267	.7
Zone 8:		
East Germany...................	195	.5
Japan		
Zone 15........................	21,597	58.4
Total..........................	36,959[a]	100.0

a/ The average total represents practically 100 percent of 1968-70 average U.S. bituminous coal exports for metallurgical use to all overseas countries; the actual coverage is 99.5 percent.

Source: Appendix table 1.

Europe, and Japan, involving seven different foreign coastal zones, by absolute tonnage and by percentage of absolute tonnage. Only countries presently or prospectively importing at least 1 million tons from the United States are included in the table. But they represent practically 100 percent of U.S. average 1968-70 bituminous coal exports for metallurgical use. Table 4 is derived from appendix table 1.

The Atlantic regions of France and Spain are included in zone 5, and the Mediterranean regions in zone 6; these two countries are the only two for which such separation had to be performed. In the case of France, practically all coking coal imports from the United States enter by way of ports in the Atlantic region.1/ In the case of Spain, the percentage entering by way of ports in the Atlantic region is a little over 90 percent; a little under 10 percent enters by way of ports in the Mediterranean region. More should be imported through the Mediterranean ports of France in the future since an integrated iron and steel complex is under construction at the new port of Fos near Marseille.

Factors Affecting U.S. Participation in World Trade in Coking Coal

Availability of U.S. Coking Coal for Export

In projecting the exports of coal for metallurgical use, aggregated and by port of shipment, consideration must be given to the locational characteristics of production and reserves of coking coal, distinguishing among the different sources according to the

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Hampton Roads Channels, Virginia, held at Norfolk, Virginia, October 21, 1970, Corps of Engineers, Norfolk District, exhibit C, p. 10.
1/ RRNA tabulation of data in U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division, Extracts from SA705, U.S. Exports, 1970.

quality characteristics considered to be relevant to their use for metallurgical purposes.

Apart from their coking qualities, characteristics considered to be most relevant are the volatile matter, ash, and sulfur content. Coals are classified according to volatile-matter content as high, medium, and low. In practice, coal from different mines falling in each of these classes is blended at the coke oven to achieve coke with optimum metallurgical characteristics. But the average volatile content for this purpose falls somewhere between the medium and low classification, so that it is these that are in greatest demand.

Whatever the volatile content or the coking characteristics of the coal, low ash and sulfur content are critical because of the adverse effects on both the quality and cost of pig iron produced from coke containing these materials. The Bureau of Mines has arbitrarily established maximum ash and sulfur contents of 8.0 percent and 1.25 percent, respectively, for coal classified as metallurgical grade.

Tables 3 and 4 (above) show production of metallurgical grade coals in the United States in 1968 and estimated (by the Bureau of Mines) remaining reserves of such coals by volatile classification and by region and state. The dominant locational characteristic of production and reserves of metallurgical-grade coals as a group is their concentration in the northern Appalachian states, and for medium- and low-volatile grades, the even higher degree of concentration in the States of Pennsylvania, Virginia, and West Virginia. These three states account for 96 percent and 99 percent, respectively, of U.S. production of medium- and low-volatile metallurgical grade coals, and 95 percent and 88 percent, respectively, of estimated remaining reserves of such coal. Only three other states (Alabama, Oklahoma, and Colorado) produce any medium-volatile metallurgical grade coal, and only one other state (Arkansas) produces any low-volatile coal.

In considering the adequacy of reserves of coal to meet long-range future requirements, one must take

into account the recoverability of these reserves and the total requirements, including both export and U.S. requirements. The Bureau of Mines uses an overall average of 40 percent as a measure of the recoverable portion of total remaining reserves. Using the data in table 4, this would indicate recoverable reserves of 27.8, 6.7, and 6.0 billion tons of high-, medium-, and low-volatile metallurgical grade coal in the United States as of January 1, 1969.

Coal carbonized by coke oven plants in the United States during 1965-69 ranged from 88.8 to 93.5 million tons. In 1969, the total was 91.7 million tons, of which 59.3, 12.8, and 19.7 million tons were high-, medium-, and low-volatile coals, respectively.1/ Similar data on exports of metallurgical coal by volatile-matter class are not available, but it is known from commercial sources and can be deduced from the locational characteristics of the origins of metallurgical export coal that the bulk is medium and low volatile.

It is anticipated that internal U.S. requirements for metallurgical coal for steelmaking purposes will be subject to the same influences as foreign requirements, discussed subsequently in this study. Technological progress and change will result in a persistent and substantial reduction in the unit consumption of metallurgical coke per ton of pig iron output. These will at least, if not more than, offset the growth in the consumption of finished steel itself. If we assume an average annual total U.S. and foreign demand for medium- and low-volatile metallurgical coal from the United States of 100 million tons annually, which is at least 50 percent greater than total U.S. consumption and estimated exports in 1969, the recoverable reserves would be equal to nearly 130 years' demand.

A similar comparison for high-volatile coal is more difficult because a substantial share of the

1/ U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1969, p. 429.

production is sold for other than metallurgical use. However, the data in tables 3 and 4 indicate a reserve equal to nearly 200 years of production at the 1968 rate.

Thus, there does not appear to be any question about the adequacy of the reserves of metallurgical grade coals in the United States to meet anticipated export demands. In this connection, it should be observed that in addition to the reserves of metallurgical grade coals, the Bureau of Mines estimates that coking coals of marginal grade and in latent reserves approximate 150 billion additional tons.

Competitive Position of U.S. Metallurgical Coal in Foreign Markets

Apart from the quality and quantity of available supplies, the competitive position of U.S. coal in foreign markets will be determined by the relative quantities and qualities of metallurgical coal available from other sources and its relative delivered price at the point of consumption. The delivered price is the sum of the mine price; brokerage fees where purchases are made from brokers; inland transport costs to port of shipment; ocean transport costs; and unloading, transport, and delivery costs to point of consumption.

Both mine prices and ocean freight rates are subject to wide fluctuation in response to changes in the supply/demand balance of metallurgical coal and ocean shipping. However, most metallurgical coal purchased by European and Japanese users is supplied under long-term contracts made directly with producers, and most ocean transportation requirements are met by long-term charters. Thus, the bulk of the supply and related transportation costs for metallurgical coal exports is insulated from the effects of short-term market influences on price. The rail transport cost from mine to port is similarly insulated by the very nature of the rail industry, whose tariffs are subject to regulation by the Interstate Commerce Commission. Thus, long-run delivered costs for U.S. exports of

metallurgical coal may be regarded as a function of long-run economic costs, except for the influence on mine price of the quasimonopoly position of U.S. suppliers of high-grade metallurgical coal.

Production and Inland Transport Costs

Data on production costs for U.S. coal are not available. In any event, costs are subject to a great deal of variation, depending upon the type of mining employed and the nature and geological conditions of the resource. Table 7 shows the average U.S. value or selling price of bituminous coal at the mine for strip mines, auger mines, and underground mines. For each of these, values fluctuated somewhat from year to year, but there is no evidence of a long-term upward trend in values from 1950 to 1968. However, there was a sharp increase in 1969, the last year for which such data are available.

Table 7 also reveals the higher values of production from underground mines, reflecting the higher production costs relative to strip and auger mines and perhaps to some extent the higher market value for high-quality metallurgical coals, all of which are produced in underground mines. In this connection, it is of interest to note that average values of underground production in Virginia and West Virginia in 1969 were $5.73 and $5.90 per net ton, compared with the national average of $5.62.1/

The increase in average values from 1968 to 1969 reflected in part increases in real economic costs resulting from increases in wage rates, and increases in production costs resulting primarily from enforcement of more stringent mine safety regulations. These influences on costs continued through 1970 and 1971, and were substantially heightened as a result of the new

1/ U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1969, p. 364.

Table 7. Average Value of Bituminous Coal, per Ton f.o.b. Mine (U.S. dollars)

Year	Strip mines[a/]	Auger mines	Underground mines	Total all mines
1940...	1.56	--	1.94	1.91
1945...	2.65	--	3.16	3.06
1950...	3.87	--	5.15	4.84
1955...	3.48	3.60	4.86	4.50
1956...	3.74	4.17	5.20	4.82
1957...	3.89	4.12	5.52	5.08
1958...	3.80	3.60	5.33	4.86
1959...	3.76	3.83	5.23	4.77
1960...	3.74	3.37	5.14	4.69
1961...	3.67	3.24	5.02	4.58
1962...	3.64	3.33	4.91	4.48
1963...	3.57	3.25	4.82	4.39
1964...	3.55	3.35	4.92	4.45
1965...	3.57	3.36	4.93	4.44
1966...	3.64	3.58	5.05	4.54
1967...	3.68	3.59	5.18	4.62
1968...	3.75	3.53	5.22	4.67
1969...	3.98	3.81	5.62	4.99

a/ Includes power strip pits proper and excludes horse stripping operations and mines combining stripping and underground in the same operation in 1940. Includes data on all strip mines subsequent to 1940.

Source: 1940-1967 -- National Coal Association, Bituminous Coal Data, 1968 edition; 1968 and 1969 -- U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1969.

labor-management contract which went into effect in the fall of 1971.

In 1968 a typical price for high-grade metallurgical coal from the Pocahontas-New River District loaded aboard vessel at the port of export was $11.00 per net ton, of which approximately $4.25 represented rail costs, and $6.75 the mine price. By the end of 1970, this cost had increased to $16.00 per ton, of which approximately $5.50 represented rail costs, and $11.50 the mine price, an increase of 70 percent in the latter during this 2-year period. The provisions of the new labor-management agreement are expected to increase average underground costs during the next 3 years by from $2.00 to $4.00 per ton, assuming no changes in productivity.

As shown in tables 8 and 9, bituminous coal productivity in the United States, which increased by 9 percent between 1965 and 1966, showed a sharp decline in its annual rate of increase and in 1970 was actually below 1969. However, of more significance to a consideration of metallurgical coal for export is productivity in the State of West Virginia, which showed an absolute and increasing rate of decline in each year after 1966, the total for the 4-year period being 8.4 percent.

Unless this decline in productivity can be arrested and reversed, there appears to be little basis for projecting anything other than a continuing long-range increase in coal production costs, because other cost functions, including the cost of mining equipment and the development of new mines, appear to offer no prospect for offsetting the increases in labor costs. This condition will be aggravated even more by the necessity for developing mines in the future with less favorable geological conditions (e.g., depth and thickness of seam) than those already developed.

Long-Term Price Prospects

Among the principal factors that would bring about or justify price increases in long-run contractual

Table 8. Bituminous Coal Productivity in the United States, January-September, 1965-70

Year	Production	Man-days	Tons per man-day	Percent change
	(1,000 tons)	(thousands)		
1965	371,992	21,684	17.16	--
1966	389,315	20,821	18.70	9.0
1967	413,049	21,989	18.78	0.4
1968	417,696	21,538	19.39	3.2
1969	409,818	21,108	19.42	0.2
1970	434,985	22,550	19.29	-0.7

Source: U.S. Department of the Interior, Bureau of Mines, Coal Mine Injuries and Work Time.

Table 9. Productivity in West Virginia in the Bituminous Coal Industry, January-September, 1965-70

Year	Production	Man-days	Tons per man-day	Percent change
	(1,000 tons)	(thousands)		
1965...	111,763	7,554	14.80	--
1966...	109,598	6,822	16.07	8.6
1967...	113,185	7,062	16.03	-0.2
1968...	113,418	7,082	16.01	-0.1
1969...	100,870	6,532	15.44	-3.6
1970...	103,705	7,034	14.74	-[illegible].5

Source: U.S. Department of the Interior, Bureau of Mines, Coal Mine Injuries and Work Time.

arrangements for the sale of metallurgical coal in export are difficulties of entry into the industry, long-run rising costs of production (which have already been discussed), and market strength on the side of sellers that succeeds in maintaining itself in the face of pressures for substitution and technological change affecting the demand for coal for metallurgical use. The U.S. coal mining industry should be able to exercise some monopoly strength given the concentration in its hands of highly desirable coking coal. However, as will be discussed later, the demand for coal for metallurgical use will probably grow slowly and eventually decline.

The monopoly position and market strength of U.S. suppliers will be enhanced by certain institutional characteristics of the industry, including increasing concentration of production in fewer mines and companies, as well as the acquisition of major coal-producing companies, coal reserves and productive capacity by petroleum and other industrial interests. The nature of this development was described in a 1969 study by the Commission of the European Communities (CEC) from which the following is quoted:

> In 1950 the 15 largest companies accounted for 27 percent of the total output. As a result of increasing concentration this share subsequently rose to 50 percent in 1967. Concentration is also taking place in the colliery level; the share in production of the 50 largest collieries rose in the same period from 13 to 25 percent.
>
> In a study of the property rights situation it is necessary to point out the large share in production which is under the control of the steel, electrical, chemical and other industries. Lately the petroleum industry has also acquired property rights in coal-mining companies, particularly in the three largest producers, namely, the Peabody Coal Company, the Consolidation Coal Company, and the Island Creek Coal Company, which in 1968 together accounted for about 27 percent of the total coal production. The last

two companies are the most important suppliers of export coal for the European and Japanese steel industries.

The coal export supply structure shows firstly that, out of a total of 5,900 pits, 400-500 are responsible for the production of export coal. In comparison, the number of actual exporters (producers and dealers) is very small, namely, 15. At this level, too, a certain concentration is to be observed. At present seven companies account for 87 percent of coal exports via Hampton Roads, 46 percent being in the hands of only four so-called producer-exporters.1/

Alternative Sources of Supply

The relative importance in world coal trade of the United States as an exporter and of Japan and Western Europe as importers in the years 1960 and 1967 is shown in table 10. These figures are for all bituminous coal, but the relative importance of metallurgical coal exports, at least from the free-enterprise countries, may be approximated from what is already known about the share of metallurgical coal in U.S. exports, and our understanding that the bulk of exports from West Germany and Australia are also from metallurgical use.

In both years the United States accounted for over 50 percent of exports from free-enterprise countries. This group was on balance a net importer of approximately 16 million tons from the state-controlled trading countries in 1967. Most of this amount was

1/ Commission of the European Communities, Report on the Question of Coking Coal and Coke for the Iron and Steel Industry of the Community, Series Energy - No. 2 (Brussels: Office of Official Publications of the European Communities, 1969), pp. 22 and 23.

Table 10. Principal Exporters and Importers on World Coal Market[a]

(Millions of tons)

	1960	1967
Exporters		
Free-enterprise countries:		
United States	34.3	45.6
West Germany	17.6	18.7
Australia	0.8	10.0
Other Community countries	5.9	5.1
United Kingdom	5.2	2.0
Other countries[b]	3.0	6.0
Subtotal	66.8	87.4
State-controlled trading countries:		
U.S.S.R.	12.8	26.0
Poland	17.5	24.0
Other countries[b]	3.5	5.0
Subtotal	33.8	55.0
Total world trade	100.6	142.4
Importers		
Free-enterprise countries:		
Japan	6.2	24.3
Benelux	11.2	13.0
Canada	12.3	14.0
Italy	9.7	12.1
France	10.1	11.6
West Germany	6.7	7.8
Other countries	--	20.7
Subtotal	--	103.5
State-controlled trading countries:		
East Germany	8.1	8.5
U.S.S.R.	4.8	7.8
Other countries[b]	--	22.6
Subtotal	--	38.9
Total world trade	100.6	142.4

a/ Including briquets.
b/ Estimate.
Source: Commission of the European Communities, Report on the Question of Coking Coal and Coke for the Iron and Steel Industry of the Community, Series Energy - No. 2 (Brussels: Office for Official Publications of the European Communities, 1969), p. 57.

from Poland, and most was steam coal rather than metallurgical coal.

The Japanese Market

The position of U.S. coal in the Japanese market relative to other sources of supply is shown in tables 11 and 12. Table 11 shows imports into Japan for 1965, 1966, and 1967, classified by coking quality and ash content. In 1967 the United States supplied 77 percent of the best quality coal, i.e., heavy coking coal with ash not over 8 percent, while most of the balance came from Australia. However, over 80 percent of total Australian supplies were of lower grades, and this was likewise true of most of the supplies from Canada and the People's Republic of China. Only 2 percent of total supplies from the United States were of the lower grades.

Of equal significance are the data in table 12, which show quantities and average value per ton of coal imported in 1968-70 by source country. In 1970, the average value of U.S. coal per metric ton was $24.68, compared with $15.30 for the U.S.S.R., $16.27 for Canada, and $14.96 for Australia. Imports from all other countries were only approximately 1 million tons of a total of 48.8 million tons.

From 1968 to 1970, the average value of U.S. coal increased $5.87 per ton, while the increase in value of imports from Australia was $2.07; from Canada, $1.03; and from the U.S.S.R., $1.22.

Because of the quality differences in coal from different sources, and the complexities of techno-economic evaluation of coal used in the manufacture of metallurgical coke, it is not possible from these data to appraise the competitive relationships of U.S. coal and coal from other sources. However, on a ton-for-ton basis this relationship worsened by anywhere from $4 to nearly $5 per ton in the period 1968-70 vis-a-vis the other principal suppliers. Under these circumstances, the incentive for the Japanese steel industry to find substitutes for U.S. coal wherever possible are apparent.

Table 11. Japanese Imports of Bituminous Coking Coal from Selected Sources of Supply, 1965-67

(Metric tons)

Year and country of origin	Heavy coking		Coal for coking	
	Ash not over 8 percent	Ash over 8 percent	Ash not over 8 percent	Ash over 8 percent
1965				
Australia	1,745,078	2,854,765	774,524	1,245,837
Canada	78,832	661,886	--	10,276
People's Republic of China	6,510	391,423	--	76,848
United States	6,744,478	27,089	--	132,225
Others	193,921	785,751	143,625	31,001
Total	8,768,819	4,720,914	918,149	1,496,187
1966				
Australia	1,832,724	3,511,927	761,548	1,946,660
Canada	13,758	759,275	--	64,531
People's Republic of China	--	561,939	5,702	89,205
United States	6,939,901	41,500	75,792	10,324
Others	233,899	1,163,695	16,147	192,261
Total	9,020,282	6,038,336	859,189	2,302,981
1967				
Australia	1,718,008	3,627,590	1,293,351	2,344,234
Canada	14,872	757,609	23	42,459
People's Republic of China	7,180	664,041	9,860	209,922
United States	9,896,431	28,388	192,247	--
Others	1,263,609	1,523,037	119,353	317,991
Total	12,900,100	6,600,665	1,614,834	2,914,606

Source: Trade of Japan (Tokyo, December 1965). Japan's Exports and Imports (Tokyo, December 1966 and December 1967); totals from U.S. Department of the Interior, Bureau of Mines, International Coal Trade, Vol. 37, No. 5, May 1968.

Table 12. Imports of Bituminous Coal into Japan

Country of origin	1970		1969		1968	
	Metric tons	Average value	Metric tons	Average value	Metric tons	Average value
		(US$)		(US$)		(US$)
Australia.......	16,470,774	14.96	15,543,041	13.42	11,985,428	12.89
Canada..........	3,216,266	16.27	929,088	15.52	993,052	15.24
People's Republic of China...	--	--	--	--	66,208	11.92
Colombia........	2,456	25.60	--	--	--	--
Germany (West)..	--	--	--	--	20,603	20.63
India...........	54,714	25.11	--	--	--	--
Mozambique......	37,352	22.68	18,603	18.31	--	--
Poland..........	892,643	16.58	1,139,540	15.90	995,960	15.63
South Africa (Rep. of)......	19,460	20.36	40,060	13.67	--	--
Turkey..........	33,679	25.90	70,884	22.05	--	--
U.S.S.R.........	2,800,458	15.30	3,056,613	14.41	2,667,327	14.08
United States...	25,239,615	24.68	19,063,513	19.08	14,228,619	18.81
Other...........	2	--	303	--	10,100	--
Total..........	48,767,419	20.16	39,861,645	16.32	30,967,297	15.88

Source: Japan's Exports and Imports (Tokyo, December 1968-70); U.S. Department of the Interior, Bureau of Mines, International Coal Trade, Vol. 40, No. 5, May 1971.

The higher cost and the recent cost increases for U.S. coal may reflect in part the quasimonopoly position of U.S. suppliers for the better grades. In this connection, it is important to note that in the 2-year period from 1968 to 1970, imports from the United States rose from 14.2 million to 25.2 million tons, an increase which contributed in a major way to an imbalance in the supply and demand for U.S. metallurgical coal, and to significant price increases in both the domestic and export markets. It is known that a substantial share of these increased Japanese imports was purchased on a spot basis in the U.S. market, contrary to the customary practice of the Japanese steel industry.

However, compared with Australia, Canada and the U.S.S.R., the higher prices for U.S. coal are also reflections of relative production and transportation cost disadvantages.

Because of the distance disadvantage of east coast U.S. ports as a source of supply to Japan, and because of the near-monopoly position of U.S. suppliers of good quality low-volatile metallurgical coal from the Appalachian area in the past, Japanese steel and trading companies have placed great emphasis in recent years on the development of alternative sources of supply, particularly in the Pacific area, as shown in table 12.

The transportation disadvantage of the East Coast as a source of supply to Japan is aggravated by the limitations of the Panama Canal on draft and deadweight capacity of bulk vessels (the maximum deadweight capacity approximates 65,000 tons). This limitation, combined with the draft limitations of the Hampton Roads ports, has lead the Japanese importers to employ bulk carriers of up to 150,000 tons' capacity, which load coal to the draft capabilities of the Hampton Roads ports and channels and then fill out the balance of the cargo with iron ore in Brazil for shipment to Japan via the Cape of Good Hope.

The development of alternative foreign sources of supply is facilitated by certain institutional

characteristics of the Japanese steel and trading industries. There are some 23 iron and steel makers in Japan. Of these, six are major: Kawasaki, Kobe, Nippon Kokan, Nippon Steel, Nisshin and Sumitomo. There are some 22 iron and steel exporters and importers. Included among them are well-known trading companies like Ataka, Itoh, Marubeni-Iida, Mitsubishi, Mitsui, Nichimen, Nissho-Iwai, Sumitomo, and Toyo Menka. The Japanese trading company is unique in world commerce. Not only may it trade in coking coal, but it may also invest in exploration and development of deposits, in local railroads to lower transport costs to export ports, and in bulk carriers to bring down the cost of transoceanic transport. There is an intimate and unique relationship between Japanese steelmakers and the trading companies.

For example, in a 13-year contract for Australian Goonyella and Peakdowns Highway coals, the development, production and shipment were jointly undertaken by the Utah Development Company, an Australian subsidiary of the Utah Construction & Mining Company, U.S.A., and by Mitsubishi Development Pty., Ltd., an Australian subsidiary of Mitsubishi Shoji Kaisha of Japan.

A 15-year contract for Australian South Blackwater coal was signed by a Director of Yawata Iron & Steel Company, representing Japanese steel mills, and the President of Thiess Brothers, Pty., Ltd.

Representatives of Mitsui & Company and Sumitomo Shoji Kaisha also signed the contract as witnesses. The two companies contributed greatly to the realization of the deal.[1/]

Japanese trading and steel interests have also participated in financing and joint venture arrangements for the production of coal in western Canada and Arkansas.

1/ H. Horie, ed., Statistical Analysis of Coking Coal Imports in Japan (Tokyo: K. Suzuki, 1969).

The European Market

While in the recent past Japan has been the main customer of American coking coal, it should be replaced by OECD Europe in the coming decades. One reason for this is that OECD Europe does not have the same access to competitive sources of supply as does Japan. Europe's major alternatives to the United States are principally Poland and the U.S.S.R.

The European Coal and Steel Community (ECSC) is closing down its uneconomic collieries. In February 1967, the ECSC Council of Ministers unanimously approved the proposal of the High Authority that it should introduce for a limited period a special scheme of aid by member states to help their coal industries lower the prices of coking coal and coke delivered to the steel industry in the Community. The collieries needed conditions which would enable them to lower their prices for coking coal and coke for use in steelworks' blast furnaces without thereby causing overhasty closure of collieries and thus hampering further efforts to adjust production.

The delivered prices of the ECSC coal-mining and coking enterprises could not be lower than those for coking coal from nonmember countries or for coke produced from coking coal from nonmember countries. In practice prices are aligned on the delivered price for coking fines from the United States or for coke manufactured from such coking fines. Simultaneously with the special scheme of aid for the coal industry, the member states set up, for a specified period and subject to certain limits, a special multilateral compensation system to share some of the costs.

In December 1969, the CEC decided on new measures which would apply for 3 years from January 1, 1970; these made some important changes compared with the previous system, notably with regard to a diminishing scale of aid from the member states.

Sixty percent of the coking plants in the EEC (whose membership is identical with that of the ECSC) presently are owned by collieries, and only 36 percent

are owned by the steel industry. However, under current investment plans, the proportion of coking plants owned by the steel industry would rise to 46 percent. These new coking plants are to be located on the coasts, as part of integrated steel mill operations, where they will have favorable access to imported coal from overseas sources.

As shown in table 13, the only important sources, other than the United States, of coal imports into the EEC are the United Kingdom, Poland, and the U.S.S.R. In the period from 1958 to 1968, the relative importance of the United States declined sharply, while that of the other three sources increased. However, in 1968 the United States still was the supplier of over 50 percent of total coal imports from all sources.

Of the other three sources, only Poland showed a persistent growth, particularly in the period from 1964 to 1968, when the volume of Community imports increased from 1.6 million to 4.1 million tons. The United Kingdom has been a more erratic supplier, with imports from that source declining from 5.6 million to 2.2 million tons during 1963-68. Like Poland, the U.S.S.R. appears to have emerged as a continuing source of supply, with imports from that source having been near or above the 3 million ton level since 1963.

The groups shown in table 13 classify coal principally according to volatile-matter content. Groups I and II are anthracite and semi-anthracite used principally for home heating. Imports from the United States declined to zero by 1967 and 1968, but this class of coal is a major share of imports from the United Kingdom and the U.S.S.R. Groups V and VI, which constitute virtually all of the imports from the United States and Poland, are understood to be mainly metallurgical coals in the low and medium volatile-matter category. They accounted for 75 percent of EEC coal imports from all sources in 1968.

Insight into the limited supplies of coking coal to member countries of the OECD from nonmembers is gained from table 14. This table is incomplete since

Table 13. Imports of Coal by the European Community from Nonmember Countries, by Grade, 1958-68[a/]

Provenance and groups	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
U.S.[b/]											
I + II........	699	158	178	374	799	2,201	823	125	50	0	0
V + VI........	22,705	13,161	11,682	10,748	12,545	16,344	17,314	18,147	16,300	13,700	10,000
III, IV + VII.	2,404	777	525	613	947	1,707	833	1,194	1,150	1,000	1,000
Total........	25,808	14,096	12,385	11,735	14,291	20,252	18,970	19,466	17,500	14,700	11,000
U.K.											
I + II........	1,175	805	913	1,347	1,957	2,838	2,412	1,388	980	681	859
V + VI........	345	366	770	1,082	981	2,555	1,614	1,111	970	745	1,315
III, IV + VII.	113	68	52	122	162	233	95	73	53	42	51
Total........	1,633	1,239	1,735	2,551	3,100	5,626	4,121	2,572	2,003	1,468	2,225
Poland											
I + II........	--	53	4	--	--	13	16	64	--	--	--
V + VI........	1,887	907	737	692	781	934	883	1,172	1,350	1,995	3,300
III, IV + VII.	687	989	961	1,087	1,059	811	709	518	708	806	795
Total........	2,574	1,949	1,702	1,779	1,840	1,758	1,608	1,754	2,058	2,801	4,095
U.S.S.R.											
I + II........	1,052	1,112	1,233	1,324	1,527	3,063	2,764	2,241	2,011	1,894	1,610
V + VI........	103	211	122	559	834	849	809	711	1,022	1,639	1,633
III, IV + VII.	15	--	--	--	--	10	--	--	--	--	--
Total........	1,170	1,323	1,355	1,883	2,361	3,922	3,573	2,952	3,033	3,533	3,243
Elsewhere											
I + II........	458	402	248	321	614	1,101	1,035	550	348	309	202
V + VI........	127	134	238	261	263	189	126	169	150	170	70
III, IV + VII.	63	90	83	91	81	114	118	85	82	102	110
Total........	648	626	569	673	958	1,404	1,279	804	580	581	382
All sources											
I + II........	3,384	2,530	2,576	3,366	4,897	9,216	7,050	4,368	3,389	2,884	2,671
V + VI........	25,167	14,779	13,549	13,342	15,404	20,871	20,746	21,310	19,792	18,249	16,318
III, IV + VII.	3,282	1,924	1,621	1,913	2,249	2,875	1,755	1,870	1,993	1,950	1,956
Total........	31,833	19,233	17,746	18,621	22,550	32,962	29,551	27,548	25,174	23,083	20,945

a/ 1966-68: breakdown partly estimated.
b/ Excluding tonnages imported direct for U.S. forces in Germany.
Source: Commission of the European Communities, An Examination of the Question of Coal Supply, 3541/1/XVII/70-E.

Table 14. Coking Coal Imports by the Iron and Steel Industry, 1969

(Thousands of tons)

Importing countries	ECSC	Other OECD Europe	Other member countries	Non-OECD countries	Total
ECSC					
Germany	35	--	237	1	273
Belgium	1,926	30	511	60	2,527
France	2,973	5	1,118	163	4,259
Italy	1,939	n.a.	1,780	n.a.	5,276
Luxembourg	--	--	--	--	--
Netherlands	n.a.	n.a.	n.a.	n.a.	n.a.
OECD Europe					
Austria	720	--	--	1,520	2,240
Denmark	--	--	--	--	--
Spain	298	--	1,617	344	2,259
Finland	--	--	--	--	--
Greece	--	--	--	--	--
Ireland	--	--	--	--	--
Norway	n.a.	n.a.	n.a.	n.a.	n.a.
Portugal	n.a.	n.a.	n.a.	n.a.	n.a.
United Kingdom	--	--	--	--	--
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	n.a.	n.a.	n.a.	n.a.	n.a.
Turkey	n.a.	n.a.	n.a.	n.a.	n.a.
Canada[a/]	--	--	5,370	--	5,370
United States	n.a.	n.a.	n.a.	n.a.	n.a.
Japan	172		19,470	18,594	38,236

a/ Official statistics are not available; figures listed are calculated on the basis of consumption by steel companies using imported coking coal.

Source: OECD, The Iron and Steel Industry in 1969 and Trends in 1970, Paris, 1970, table 18C.

data were not available for all importing countries. However, it is clear that for their coking coal supplies all European OECD countries, other than Austria, depend almost entirely on other European members of the OECD and on other member countries, of which only the United States is a coal exporter.

The energy policies of the EEC countries mentioned earlier will result in a continuous long-term decline in indigenous production of coal, so long as imported sources of energy, including coking coal, are more economic than indigenous coal. Even with the increased costs and prices for U.S. coal in recent years, it seems unlikely that it would not compete successfully in both quality and economic terms with most European coal. Other import sources for coking coal are almost entirely limited to Poland and, possibly, Australia. Poland's resources and productive capacity of coking coal are limited, and priority is given to markets within the Soviet bloc. Australia is having difficulty meeting its commitments to Japan, and is much less advantageously located to the European market than is the United States. The United Kingdom and the U.S.S.R. are not considered potential sources of coking coal for Western Europe, largely because of the limitations on their own resources and the priority given to meeting the requirements of the steel industries of those two countries.

Future Roles of the U.S.S.R. and the People's Republic of China as Suppliers of Coking Coal

Both the U.S.S.R. and the People's Republic of China seem to have actual or potential significance as sources of coking coal in the Japanese market. As already shown, the U.S.S.R. has become an important source of coking coal to Japan. This coal is being supplied under a 1968 agreement, by which a total of 23 million tons of coking coal is to be supplied over a 7-year period. However, it is produced in the Asian sphere of the U.S.S.R., and is more advantageously located to Japan than to the European markets. The People's Republic of China is known to have substantial reserves of coking coal (see annex A-8). However, the extent to

which necessary investments will be made in the development of productive and beneficiation capacity to meet not only internal needs but the needs of export markets such as Japan is problematical. If political and cultural obstacles to the transfer of needed capital and technical resources from Japan to the People's Republic of China can be overcome, the potential exists for the emergence of China as a major source of coking coal to Japan, and, therefore, as another alternative to imports from the United States.

Forecast of U.S. Exports of Coking Coal to OECD Europe and Japan in 1980 and 2000

Method

Our method consists of the following principal steps:

1. Projections of crude steel production for both OECD Europe and Japan in the years 1980 and 2000

2. Forecasts of the structure of crude steel production by furnace type

3. Forecasts of the pig iron/scrap proportion by steel furnace type

4. Projections of pig iron production

5. Forecasts of specific consumption of blast furnace coke per ton of pig iron

6. Calculation of total coke consumption and coal equivalent

7. Estimates of U.S. exports of coking coal to both OECD Europe and Japan in the years 1980 and 2000.

Production of Crude Steel

Anticipated long-run trends in consumption of crude steel per capita, population, and trade in steel compose the elements of the projection of crude steel.

OECD Europe

In 1968 apparent consumption of steel in OECD Europe was 124.3 million metric tons; population was 364.3 million; apparent steel consumption per capita was 341 kilograms, or 755 pounds. By projecting both consumption of crude steel per capita and population size for the years 1980 and 2000, we implicitly project consumption of crude steel for these years. With respect to the former, the principle we chose to follow was to make OECD consumption per capita by the year 2000 approach the highest present consumption levels elsewhere. (These levels are in the vicinity of 700 kilograms and are to be observed in the United Sates and Sweden.) This resulted in apparent consumption of crude steel per capita of about 500 kilograms in 1980, and of 700 kilograms in 2000. The resulting levels of consumption of crude steel in OECD Europe using the population projections in annex A-1 are 201.5 million and 340.9 million metric tons in 1980 and 2000, respectively.

Production is equal to consumption, plus or minus the balance of trade in steel, which in recent years has been positive (table 15). Changes in stocks are ignored.

It is assumed that OECD Europe maintains throughout the 30-year period a positive net balance of trade in steel amounting to 10 percent of production. Projections of crude steel production are, then, 223.7 million tons in 1980 and 378.4 million tons in 2000 (table 16).

By way of comparison for 1980, a CEC study forecasts for the total of the EEC, the United Kingdom, and the rest of Western Europe high, medium, and low production levels of 205, 196 and 187 million metric tons, respectively.[1]

1/ Commission of the European Communities, Report on the Question of Coking Coal, p. 51.

Table 15. OECD Europe: Net Balance of Trade in Steel, 1967-1969

(In millions of metric tons)

Year	Production	Consumption	Net balance of trade in steel	
			Tons	Percentage of production
1967.....	129	114	+15	11.6
1968.....	142	125	+17	12.0
1969.....	154	144	+10	6.5

Source: OECD, The Iron and Steel Industry in 1969 and Trends in 1970 (Paris, 1970), Tables 2 and 28.

Table 16. Projections of Production of Crude Steel in OECD Europe and Japan in 1980 and 2000

(In millions of metric tons)

Area	1968	1980	2000
OECD Europe			
Consumption of crude steel per capita (kgs.)	341	500	700
Population (millions)	364.3	402.9	487.0
Consumption of crude steel	124.3	201.5	340.9
Net balance of trade in steel (percent of production)	12.0	10.0	10.0
Production of crude steel	142.5	223.7	378.4
Japan			
Consumption of crude steel per capita (kgs.)	494	750	850
Population (millions)	101.1	116.3	132.8
Consumption of crude steel	49.9	87.2	112.9
Net balance of trade in steel (percent of production)	25.7	15.0	10.0
Production of crude steel	66.9	102.9	125.3

Source: Consumption of crude steel in 1968 -- United Nations Statistical Yearbook 1969 (New York, 1970), p. 491.

Population -- Annex A-1, table 9.

Production of crude steel in 1968, OECD, The Iron and Steel Industry in 1969 and Trends in 1970 (Paris, 1970), Table 4; 1980 and 2000, estimated by Robert R. Nathan Associates.

Japan

Apparent consumption of crude steel per capita has risen very rapidly in Japan, from 291 kilograms in 1965 to 602 in 1969.1/ The 1969 figure fell only 110 kilograms short of the figure for Sweden, the world's highest, and only 80 kilograms short of the figure for the United States.

The explanation of the high level of consumption of steel per capita in Japan lies mainly in the character of its exports. In recent years the crude steel equivalent of exports of steel mill products were the following percentages of crude steel production: 1965, nearly 31 percent; 1966, nearly 27 percent; 1967, 19 percent; 1968, nearly 26 percent; and 1969, nearly 26 percent.2/

Japan also exports steel in highly steel-intensive products. Precisely how much is a complex calculation. Steel may be an important direct input for an industry (e.g., automobiles and other transport equipment), but steel may also be an important indirect input for an industry (i.e., the industry may not purchase steel at all, but may purchase a variety of inputs which use steel).

Input-output coefficients attempt to measure the total direct and indirect gross output of steel needed to support one unit of final demand of a given commodity. Consulting the input-output structure of the U.S. economy, we determined to call an industry a highly steel-intensive one if it needed, directly and indirectly, a total of 15 cents or more of blast-furnace and basic steel products per $1 of delivery of final demand.3/

1/ The 1969 figure is from OECD, The Iron and Steel Industry in 1969 and Trends in 1970, table 29; 1965 is from U.N. Statistical Yearbook 1969, p. 491.
2/ S. Kawata, ed., Japan's Iron and Steel Industry, 1970 ed. (Tokyo: Kawata Publicity, 1970), p. 264.
3/ U.S. Department of Commerce, Office of Business Economics, Input-Output Structure of the U.S. Economy:

This definition was then applied to Japanese exports, since investigation has shown that input coefficients, especially in manufacturing, in one country have a considerable similarity to input coefficients in other industrialized countries.1/ The high level steel-using industries, besides primary metal industries, are metal furniture, fabricated metal products, machinery, transportation equipment, electrical machinery, and household appliances.

The highly steel-intensive character of Japan's exports emerges clearly from table 17. In 1969, iron and steel were 13.5 percent of her exports by value, but other high steel-using products were more than twice that; in 1970, these two classes of exports approached 50 percent of total commodity exports. We have not estimated how much of apparent consumption of crude steel in Japan is in fact not consumed but exported in other high steel-using products. That would be a sophisticated undertaking which the form of these data does not allow. Still, our findings suggest strongly that Japan's apparent consumption of crude steel per capita grossly overstates her actual consumption.

In the projections for Japan (table 16), we assume that apparent consumption per capita will rise to 750 kilograms by 1980, and that Japan will have a positive trade balance in steel of 15 percent of crude steel production. By 2000 we assume that apparent consumption per capita will have risen to 850, and that the positive trade balance will amount to 10 percent of crude steel production.

1963, vol. 3, Total Requirements for Detailed Industries, 1969; Executive Office of the President, Bureau of the Budget, Standard Industrial Classification Manual, 1957; U.S. Department of Commerce, Bureau of the Census, U.S. Foreign Trade Statistics, Classifications and Cross Classifications, 1970, "Correlation Between Schedule B Export Classifications and Agricultural, Nonagricultural, SITC, FT 990, End-Use and SIC-Based Product Codes."
1/ H. B. Chenery and P. G. Clark, Interindustry Economics (New York: John Wiley and Sons, Inc., 1959), p. 211.

Table 17. Japan's Exports of Iron and Steel and Other Highly Steel-Using Products, 1969 and 1970

Exports	1969	1970
	Millions of dollars	
Iron and steel..........	2,164.8	2,843.7
Other highly steel-using products.........	4,841.8	6,231.0
Subtotal.............	7,006.6	9,074.7
Total commodity exports.	15,990.0	19,317.7
	Percent	
Iron and steel..........	13.5	14.7
Other highly steel-using products.........	30.3	32.3
Subtotal.............	43.8	47.0
Total commodity exports.	100.0	100.0

Source: Japan's Exports and Imports (Tokyo, December 1969 and 1970), pp. 7-21.

These projections of Japan's crude steel output may appear conservative, considering that production reached 89.5 million metric tons in 1970. Two considerations weighed heavily in these projections:

1. Consumption of steel per capita in mature economies, such as Japan will be, appears to reach a plateau. The range of 750 to 850 kilograms seems a reasonable assumption based on observation in the countries. It is roughly comparable to the crude steel per capita consumption projected for the United States (see annex A-3 on iron ore imports). Coupled with this is the slow growth of Japan's population.

2. The comparative advantage of the Japanese steel industry will diminish as others adopt the best available techniques and as the rise of wages in Japan catches up with or surpasses the rise in productivity. This development will be accelerated by the devaluation of the yen in relation to the dollar.1/

In support of this, a summary of a recent study of Japan's economy by the staff of thr General Agreement on Tariffs and Trade (GATT), appearing in the New York Times, stresses:

> The "structure and dynamics" of the Japanese economy will retain distinctive features, the [GATT] study says. Nevertheless, the staff expects the differences with other countries to narrow with Japan gradually losing her role as supplier of manufactured goods produced with low-cost labor....At the end of the 1965-70 boom, the "longest and strongest" in Japan's postwar history, the Japanese economy reached a "watershed" with symptoms pointing to a "far-going structural change" ahead, according to the GATT study. The symptoms leading to this prediction were listed

1/ In 1968 Japan exported 5.7 million metric tons of steel mill products to the United States, or 35 percent of total exports.

as being a serious labor shortage, considerable inflationary tensions and a very substantial structural trade surplus.

The CEC forecasts by 1980 crude steel production for Japan of 105 million tons as a medium estimate. The high and the low estimates are 110 and 100 million tons, respectively.1/

Forecast of Pig Iron Production

The forecast of pig iron production in OECD Europe and Japan involves somewhat the same factual and analytic process employed for the forecasts of iron ore consumption in the United States (see annex A-3). The primary use of metallurgical coke by the steel industry is in the production of pig iron in blast furnaces, and the requirement for metallurgical coke and coking coal is therefore a function of pig iron production in the same way as is the requirement for iron ore.

The essential elements of the analysis are the present and prospective structure of steel production by type of furnace, and present and projected inputs of the basic metallics, i.e., pig iron and iron and steel scrap. The proportions of steel production by type of furnace in 1969 in OECD Europe and Japan are shown in table 18. They differ with each other and with the structure in the United States in several respects. Nearly 18 percent of European output is bessemer, of which Japan has none, and there is virtually none in the United States. Of total U.S. output, 37 percent was from open hearth furnaces, considerably more than in either Europe or Japan. The proportions of electric furnace output are pretty much the same in all three areas, but Japan produces nearly 77 percent from basic oxygen furnaces, compared with 37 percent in Europe and 48 percent in the United States.

1/ Commission of the European Communities, Report on the Question of Coking Coal, p. 51.

Table 18. Structure of Steel Production by Steel-Furnace Type, 1969

Area and furnace type	Percent
OECD Europe	
Basic bessemer steel (including acid bessemer steel)	17.9
Open hearth steel	28.5
Electric steel	16.3
Basic oxygen steel	37.3
Total	100.0
Japan	
Basic bessemer steel (including acid bessemer steel)	--
Open hearth steel	6.4
Electric steel	16.7
Basic oxygen steel	76.9
Total	100.0

Source: OECD, The Iron and Steel Industry in 1969 and Trends in 1970, Tables 5a, 5b, 5c, 5d, 5e.

As in the United States, the future trend in Europe and Japan is expected to be in the direction of almost exclusive production from basic oxygen and electric furnaces. Our projections of output by type of furnace in Europe and Japan for 1980 and 2000 are presented in table 19.

Table 20 shows our projections of metallic inputs by type of furnace for Europe and Japan for 1980 and 2000. The pig iron and scrap proportions in the basic oxygen furnace are identical to those employed in the projections for the United States, and the proportions for the open hearth and electric furnaces do not differ substantially. The relative inputs for the basic bessemer furnace, which will be used in Western Europe in 1980 but not in the United States or Japan, are based on present utilization rates in Europe.

The projections of crude steel production and the forecasts of the structure of crude steel production and of the pig iron/scrap proportion by furnace type result in the following pig iron/steel ratios:

Area	1980	2000
OECD Europe	54.7	53.1
Japan	56.5	53.1

These ratios have to be raised by 10 percent to account for the fact that about 1.1 tons of pig iron and scrap are consumed in the production of 1 ton of crude steel. This input-output relation varies a little among steel furnaces and between conventional methods and continuous casting.

The adjusted ratios and our projections of crude steel and pig iron production in OECD Europe and Japan in 1980 and 2000 appear in table 21. From our forecast, in OECD Europe the pig iron/steel ratio will fall by about 10 percentage points by 1980 and by only about 2 between 1980 and 2000; in Japan, it will fall by 9 percentage points by 1980 and by only about 4 between 1980 and 2000. Clearly, the disappearance of the basic

Table 19. Structure of Production of Crude Steel in OECD Europe and Japan, by Steel-Furnace Type, 1980 and 2000

(In percent)

Furnace type	OECD Europe		Japan	
	1980	2000	1980	2000
Basic bessemer....	10.0	--	--	--
Open hearth.......	15.0	--	--	--
Basic oxygen......	55.0	75.0	80.0	75.0
L.D..............	50.0	68.2	72.7	68.2
Kaldo............	5.0	6.8	7.3	6.8
Electric..........	20.0	25.0	20.0	25.0

Table 20. Pig Iron/Scrap Proportions by Steel-Furnace Type, 1980 and 2000

(In percent)

Steel furnace[a]	Pig iron	Scrap
Basic bessemer..........	90.0	10.0
Open hearth.............	45.0	55.0
Basic oxygen............	70.0	30.0
Electric................	2.4	97.6

a/ Open hearth and Kaldo (a basic oxygen process) furnaces can vary their proportions; electric and L.D. (another basic oxygen process) furnaces apparently cannot. The fixed proportion of the L.D. process is 70:30; the Kaldo process is assumed to operate at this same proportion, and its share of output is assumed to be 10 percent of the share of L.D.

Table 21. Projections of Production of Pig Iron in OECD Europe and Japan, 1980 and 2000

(In millions of metric tons)

Production	OECD Europe			Japan		
	1969	1980	2000	1969	1980	2000
Crude steel....	154.3	223.7	378.4	82.2	102.9	125.3
Pig iron (pct. per ton of crude steel)..	70.4	60.2	58.4	71.1	62.1	58.4
Pig iron.......	108.7	134.7	221.0	58.4	63.9	73.2

Source: All figures for 1969 are from OECD, The Iron and Steel Industry in 1969 and Trends in 1970, Tables 3 and 4. Pig iron production includes blast furnace ferro-alloys. This hardly affects the ratio of pig iron to crude steel in 1969.

bessemer furnace and the growing importance of the electric furnace result in an increase in the share of scrap.

The Coke/Pig Iron Ratio

For more than three centuries the coke blast furnace has been the dominant instrument for the reduction of iron ore to pig iron. A question that looms large is how long this will continue. For some time, it has been possible to reduce iron ore directly without employing coke, and direct reduction furnaces are in commercial use.

In addition, more has been done to increase the efficiency of the coke blast furnace in the past decade than was done in the past century.1/ The result has been the steady, marked decline in the consumption of coke per ton of pig iron produced -- the coke ratio (table 22).

While the rising cost of coke has been giving new impetus to the perfection of large-scale direct reduction techniques, there is a very wide consensus2/

1/ Department of the Interior, Bureau of Mines, Mineral Facts and Problems, 1965, p. 462.

2/ The Commission of the European Communities, in Report on the Question of Coking Coal (p. 7) stated that "The general consensus is that [up to 1980] the blast furnace used with oxygen blower converters will continue to dominate steel production." William Bellano, in World Metallurgical Coal in the Seventies (address to a meeting of the International Iron and Steel Institute, Paris, October 13, 1970), stated (p. 9) that "We must conclude, however, that no process of direct reduction of ores will substantially change the predictions made for coke to be used in steel production by 1980. In this we are joined by most experts in the field, including the renowned Dr. H.M. Finniston, Deputy Chairman of the British Steel Corporation, who said, during his Coal Science Lecture last year in reviewing the many alternatives being considered: 'As of today, the blast furnace is likely to be with us for a very long time ahead as the major source of reduced ore.'"

Table 22. Trend of Specific Consumption of Blast-Furnace Coke per Ton of Pig Iron

(In kilograms)

Area	1960	1967
Free-enterprise countries		
Community	890	620
United Kingdom	825	656
Rest of Western Europe	--	660
U.S	749	639
Canada	--	555
Latin America	--	700
Africa	--	773
Middle East	--	--
Japan	617	496
India	--	845
Rest of Asia	--	790
Australia	--	608
Subtotal	--	620
State-controlled trading countries		
U.S.S.R	711	600
Other East European countries	--	710
People's Republic of China	--	867
Subtotal	--	657
Total	--	632

Source: Commission of the European Communities, Report on the Question of Coking Coal, p. 53.

both in the coal and in the iron and steel industry that at least until 1980 the coke blast furnace will continue to be the chief instrument for the reduction of iron ore. On the other hand, the coke ratio will continue to decline as the current best practice and innovations are gradually adopted.

Today, under optimum technical conditions, "If coke alone is used, 450 kilograms of coke are required to produce one ton of pig iron in the blast furnace.... This quantity could be reduced by about 10 to 15 percent, i.e., to roughly 400 kilograms, by the use of other energy carriers, and could be cut further by the use of pre-reduced ore."1/

A Japanese publication states:

> ...to be taken into account...is the possibility that the coke rate in the blast furnace practice will decrease drastically in future to 250 kilograms per ton of pig iron output (about half of the current rate) [in Japan].
>
> The decrease of the coke rate will be brought about by the increase in the substitute use of heavy oil and noncoking coal and also indirectly by the increasing use of pellets and sinters, which require less coke in blast furnace practice than lump ores.2/

The 1970 edition of Japan's Iron and Steel Industry contains the following statement:

> Thanks to the utmost efforts for the saving of coke consumption so as to meet the ever-tightening supply of coking coal, the nation-wide coke rate

1/ Commission of the European Communities, Report on the Question of Coking Coal, pp. 7 and 8.
2/ H. Horie, ed., Statistical Analysis, p. 4.

came down to 482 kg in March, 1970, from the 499 kg at the end of 1968. This was achieved by high temperature blasting, increased fuel injection, and oxygen-enrichment.

Almost all newly-built and remodelled blast furnaces have adopted high top pressure operation. The top pressure now being adopted is usually 1.0 to 1.5 kg/cm^2.

In most high top pressure blast furnaces, the unique material charging device -- the main device for high top pressure operation -- of Japanese origin is used....

Besides, two blast furnaces designed for ultra-high top pressure operation are now being operated by Nippon Steel. Built to USSR design, these furnaces have a maximum top pressure of 2.5 kg/cm^2....

The hot stoves equipped in recently-built large size blast furnaces have separate combustion chambers, and the refractory linings of these hot stoves are made of silica bricks which permit 1,250° to 1,300° C high-temperature blasting. The new blast furnaces at Nippon Kokan's Fukuyama Works and Kawasaki Steel's Mizushima Works are equipped with the Koppers type hot stoves of this kind which permit 1,150° C to 1,200° C blasting....

In an attempt to reduce coke rate, oxygen-enrichment and fuel (incl. heavy oil) injection have been studied with special interest. These two practices are being adopted together with the high-temperature blasting.

The purpose of oxygen-enrichment in blasting is to avoid the dropping of temperature at the furnace hearth when heavy oil is

injected from furnace tuyeres, and to assist combustion of fuel in front of tuyeres. The oxygen-enrichment also helps increase productivity of blast furnaces. Usually 1-30% oxygen is added in blasts, but the rate is expected to increase further.

A success in this technique was achieved by the No. 1 blast furnace (1,959 m^3) at Nippon Steel's Tobata Area Works in March 1970. The furnace recorded an average daily output of 3,762 tons and a coke rate of 393 kg with oxygen-enrichment rate of 2.77%, 1,100° C blasting and heavy oil injection of 85 kg per ton of pig iron produced. [Underscoring supplied.]

Developmental research is now underway on a new process of reducing gas injection into blast furnaces jointly by Nippon Steel and Texaco Development Corp. of the U.S. Known as the F-T-G Process, this process is a method of partially oxidizing liquid fuels such as heavy oil in a special cracking furnace, and then injecting high-temperature reducing gas thus produced into the reduction zone of a blast furnace. This process is now being adopted in the No. 3 blast furnace (1,691 m^3) at Nippon Steel's Hirohata Works. The furnace, equipped with a 5 t/hr cracking furnace, is being injected with reducing gas at the rate of 100 m^3 per ton of pig iron produced for the anticipated reduction of coke rate by 30-35 kg. [Underscoring supplied.] It is considered possible that as the volume of reducing gas injected is increased, coke consumption can be reduced accordingly. It also will be possible that atomic power is utilized for fuel cracking.1/

1/ S. Kawata, ed., Japan's Iron and Steel Industry,

While at the present time it is impossible to predict actual proportions with any measure of confidence, after 1980, alongside the decline in the coke/pig iron ratio, there will be increasing displacement of the coke blast furnace by alternative methods of reducing iron ore, which would eliminate the need for metallurgical coal for iron production.

In this connection Bellano states, "The Japanese hope to have an experimental atomic reactor for tests using nuclear power to replace coking coal for making steel by 1972."1/

Our forecasts of the coke ratio for 1980 assume that the blast furnace will dominate, but that the cost of coke will continue to force the rate down. In 2000 the coke blast furnace is assumed to coexist with a variety of direct reduction techniques. Our forecast of the coke rate in 2000 is the product of the proportion of iron produced with coke and of blast furnace coke consumption per ton of pig iron. This implies that the actual blast furnace coke rate is higher than 250 kilograms of coke per ton of blast furnace pig iron.

Table 23 presents our forecast of the trend in kilograms of specific consumption of blast furnace coke per ton of pig iron to 1980 and 2000.

Coking Coal Requirements

Projections of the production of pig iron and the coke rate allow us to derive the steel industry's coke consumption. Assumptions about the share that steel industry coke consumption will be of total coke consumption in OECD Europe and Japan in 1980 and 2000 permit forecasts of coke production. Total coke production in both regions and in both years was converted to coal equivalent by multiplying by 1.31. The assumed

1970 ed. (Tokyo: Kawata Publicity, Inc., 1970), pp. 71-73.

1/ William Bellano, World Metallurgical Coal, p. 10.

Table 23. Trend of Specific Consumption of Blast-Furnace Coke per Ton of Pig Iron, 1980 and 2000

(In kilograms)

Area	1969	1980	2000
OECD Europe........	591	500	250
Japan..............	493	400	250

Source: OECD, The Iron and Steel Industry in 1969 and Trends in 1970, Tables 3 and 20.

share and resulting requirements are shown in table 24. The increase in steel's share of total coke consumption is the continuation of an established trend in the decline of consumption for other uses, such as space heating.

U.S. Exports of Coking Coal to OECD Europe and Japan in 1980 and 2000

In deriving these forecasts, we must establish, first, what proportion of the coking coal requirement might be satisfied from domestic sources; second, what alternative sources of supply exist for the proportion that must be satisfied by imported coking coal; and third, what share of the latter will be supplied by the United States. Our forecasts of indigenous supplies and imports from the United States and other sources are given in table 25, compared with 1968 and 1969 actual amounts.

OECD Europe

OECD Europe's main steel producers are, in order, West Germany, the United Kingdom, France, Italy, Belgium, Spain, Sweden, Luxembourg, and the Netherlands. Its main coking coal importers are Italy, France, the Netherlands and Belgium, and its main coking coal exporter is West Germany.

Table 24. Coke and Coking Coal Requirements in OECD Europe and Japan in 1980 and 2000

(In millions of metric tons)

Item	OECD Europe			Japan		
	1969	1980	2000	1969	1980	2000
Production of pig iron..........	108.7	134.7	221.0	58.4	63.9	73.2
Steel industry's coke consumption..	64.3 a/	67.4	55.3	28.8 a/	25.6	18.3
Total coke production...........	92.9 a/	79.3	56.7	37.0 a/	26.9	18.8
Total coke production in coal equivalent b/......	121.7	103.9	74.3	48.5	35.2	24.6
Steel industry's coke consumption as percent of total coke production.............	69.3	85.0	97.5	78.0	95.0	97.5

a/ OECD, The Iron and Steel Industry in 1969 and Trends in 1970, tables 17 and 20.
b/ Total coke production multiplied by 1.31, the average in the OECD in the years 1954-68; OECD, Statistics of Energy, 1954-1968, Paris, 1970.

Table 25. U.S. Exports of Coking Coal to OECD Europe and Japan: Forecasts to 1980 and 2000, with Recent Experience

(In millions of metric tons)

Item	Recent experience						Forecasts			
	OECD Europe		ECSC		Japan		OECD Europe		Japan	
	1968	1969	1968	1969	1968	1969	1980	2000	1980	2000
Total coke production[a/]	88.8	92.9	65.1	68.5	30.5	37.0	79.3	56.7	26.9	18.8
Total coke production in coal equivalent[b/]	116.3	121.7	86.0[c/]	91.1	40.0	48.5	103.9	74.3	35.2	24.6
Domestic coking coal	n.a.	n.a.	77.0[d/]	79.9	12.4[d/]	12.5	62.3[e/]	30.0	3.5	2.5
Imported coking coal	n.a.	n.a.	9.0[c/]	11.2	28.8[d/]	38.2	41.6	44.3	31.7	22.1
Coking coal imports from U.S.	9.4[f/]	10.0[f/]	6.9[f/]	7.4[f/]	13.7[d/]	18.7	31.2	33.5	12.7	7.3
Coking coal imports from U.S. as percentage of imported coking coal	n.a.	n.a.	.77	.66	.48	.49	.75	.75	.40	.33

a/ OECD, The Iron and Steel Industry in 1969 and Trends in 1970, Table 17.
b/ Total coke production multiplied by 1.31, the average in OECD for 1954-68; actual figures in the case of ECSC.
c/ Commission of the European Communities, An Examination of the Question of Coal Supply, Annex 2.
d/ S. Kawata, ed., Japan's Iron and Steel Industry, p. 276.
e/ Domestic coking coal is 60 percent of requirements in OECD Europe in 1980; it is 10 percent of requirements in Japan in 1980 and in OECD Europe and Japan in 2000.
f/ Appendix table 1.

In 1969, the EEC produced 73 percent of OECD Europe's pig iron and 70 percent of its crude steel. In 1970, the EEC supplied 85 percent of its own coking coal requirements. But this proportion must change toward a greater reliance on imports. A very recent publication of the CEC, An Examination of the Question of Coal Supply and Production in the Community, estimated that by 1975 31 percent (or 28.5 million metric tons) of the EEC's coking coal requirements would be imported, and production would be down to 63 million tons from 79.9 million in 1969. A further indication is the fact that new coking plants being constructed by the EEC's steel industry are principally on the coasts.[1/]

We have assumed that in 1980 domestic coking coal would supply 60 percent of requirements, and in 2000, 40 percent. For both years, we have also assumed that imports from the United States would be 75 percent of total imports. This results in total coking coal imports of 41.6 and 44.3 million tons in 1980 and 2000, respectively, of which 31.2 and 33.5 million tons would be from the United States.

These quantities and relationships are broadly consistent with studies and evaluations by the EEC of the long-term trends in indigenous production of coking coal, and of the limitations on foreign sources of supply other than the United States. As discussed earlier in this report, only Poland and the U.S.S.R. are present or potential European sources of imports, and resources available from each of these are limited in both quantitative and qualitative terms. The Polish coal, for example, is not a substitute for the low-volatile coking coal presently imported from the United States.

Australian coal suffers a somewhat similar handicap, which is further aggravated by Australia's unfavorable geographical relationship to Western Europe when

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1/ Dr. Oskar Schumm, "Prospects for the European Communities' Future Coal Supplies," Address to the Joint Session of the National Coal Association and Coal Exporters Association of the U.S., Inc., Washington, D.C., June 15, 1971.

compared with that of the United States, and by the demands of the Japanese steel industry, where Australia enjoys a significant transportation advantage over the United States.

Japan

For Japan we have assumed that indigenous production will continue to supply 10 percent of total coking coal requirements in both 1980 and 2000, and that the share of the United States in the Japanese import market will be 40 percent and 33 percent in the two forecast years respectively. In absolute numbers, imports from the United States would be 12.7 and 7.3 million tons.

This decline in the U.S. share is consistent with the increasingly successful efforts of Japan to develop alternative sources of supply for coking coal, chiefly in the Pacific area. In this connection, data presented in table 26 and in appendix tables 2 to 5 on scheduled deliveries under long-term contracts with suppliers in the United States, Australia, the U.S.S.R., and Canada, are instructive. For the year 1975, for example, scheduled deliveries from both Australia and Canada exceed those from the United States, and this is also true of 1980. It is known that difficulties are being encountered by both Australia and Canada in meeting their commitments under these contracts, but it is assumed that these difficulties will eventually be overcome. Commitments from these two sources alone for 1980 equal 20 million tons, roughly equal to total estimated import requirements from non-U.S. sources in that year. On the other hand, contract commitments from the United States as of the time that these data were compiled were equal to approximately half of estimated imports from the United States.

Forecasts of Exports of Coking Coal

Table 27 allocates the forecasts of U.S. exports of coking coal to OECD Europe and Japan in 1980 and 2000 by exporting districts, exporting ports and

Table 26. Summary of Japan's Long-Term Contracts for Importation of Coking Coal

(In thousands of long tons)

Country	1975[a]	Percent	1980[a]	Percent
United States[b]...	10,350	25.2	6,640	24.9
Australia[c]......	15,050	36.6	8,000	30.0
U.S.S.R.........	3,590	8.7	--	--
Canada[d]........	12,150	29.5	12,000	45.1
Total.........	41,140	100.0	26,640	100.0

a/ Fiscal.
b/ Itmann, Keystone, and Beatrice-Virginia Pocahontas brands; all low-volatile coals.
c/ All heavy coking coal.
d/ Hard coking coal.

Source: H. Horie, ed., Statistical Analysis, pp. 33, 48, 144, 162.

Table 27. U.S. Overseas Coking Coal Exports, 1980 and 2000: Exporting Districts; Exporting Ports; Overseas Destinations

(Millions of metric tons)

U.S. overseas exports	1980	2000
Exporting districts		
Districts 1, 3 and 6[a/]	1.5	0.5
Districts 7 and 8 (Va. and W. Va.)	46.9	47.4
Alabama[b/]	1.0	0.5
All others[c/]	0.5	0.5
Exporting ports		
Hampton Roads	46.9	47.4
Baltimore	1.5	0.5
Mobile/Pascagoula	1.0	0.5
Texas-Louisiana ports	0.5	0.5
Overseas destinations		
South America:		
Zone 3	0.5	0.8
Zone 4	4.5	6.2
Total	5.0	7.0
OECD Europe:		
Zone 5	18.4	19.2
Zone 6	12.3	12.8
Zone 7	0.5	1.5
Total	31.2	33.5
Other Europe:		
Zone 7	0.5	0.5
Zone 8	0.5	0.6
Total	1.0	1.1
Japan:		
Zone 15	12.7	7.3
Overseas total	49.9	48.9

Note: Overseas exports do not include exports to Canada, which go by lake and rail.

a/ It is assumed that all District 1, 3, and 6 coal is destined for Northern Europe.

b/ It is assumed that all Arkansas coal is destined for Japan.

c/ It is assumed that Alabama coal is divided equally between Japan and Northern Europe.

overseas destinations defined in terms of the coastal zones employed in this study for all U.S. exports and imports. To them have been added forecasts for zones 3 and 4 of South America, the former comprised of Chile, the latter of Argentina and Brazil, and for zones 7 and 8 of other Europe, the former comprised of Yugoslavia, the latter of East Germany.

In the future, foreign steel industries will continue to purchase mainly low-sulfur, medium- and low-volatile coking coals. Districts 7 and 8 in southern West Virginia and southern Virginia are the principal origins of these coals. Hence the greater part of U.S. overseas coking coal exports are projected to come from these districts.

The share of Hampton Roads as principal exporting port does not change much. Mobile may appear increasingly as an exporting port for Alabama coking coal, but based on present knowledge, it is not expected to become of greater importance than some of the present-day minor exporting ports. Beyond this, it is now very difficult to say whether and to what extent new U.S. ports will enter the coal trade.

U.S. 1968-70 average overseas coking coal exports were 33.6 million metric tons. Overseas exports are projected at 49.9 million metric tons in 1980 and 48.9 million tons in 2000 (table 28). However, a major change in the shares of the principal destinations would take place.

Table 28. Overseas Coking Coal Exports to Japan and OECD Europe

Year	OECD Europe		Japan	
	Million tons	Percent	Million tons	Percent
1968-70....	11.1	33.0	19.6	58.0
1980.......	31.2	62.5	12.7	25.5
2000.......	33.5	68.5	7.3	14.9

Not only would Japan's relative share of U.S. overseas coking coal exports decline, but her absolute volume would also decline. OECD Europe's relative share of U.S. overseas coking coal exports, as well as her absolute volume, will rise.

Within OECD Europe, zone 5 presently receives approximately two-thirds of U.S. overseas coking coal exports to zones 5 and 6. In the future, developments along the Mediterranean coasts of France and Spain and in Italy will tend to bring a higher proportion of U.S. coking coal to zone 6. We assume that in 1980 and 2000 40 percent of U.S. exports to the two zones will go to zone 6 and 60 percent to zone 5.

APPENDIX

Appendix table 1. Estimated End Use of U. S. Bituminous Coal Exports, by Countries, in Thousand Short Tons, 1961-70
Part I. 1961-65

Destination	1961		1962		1963		1964		1965 a/	
	Metallurgical use	Total Exports	Metallurgical use	Total Exports	Metallurgical use	Total Exports	Metallurgical use	Total Exports	Metallurgical use	Total Exports
North America:										
Canada	4,769	11,169	4,872	11,410	5,876	13,752	6,063	14,187	6,000	15,661
Mexico	54	54	51	51	47	47	54	54	60	60
Other	—	6	—	15	—	11	—	6	—	6
Total	4,823	11,229	4,923	11,476	5,923	13,820	6,117	14,247	6,060	15,727
South America:										
Argentina	577	577	670	671	531	531	765	765	620	620
Brazil	778	979	1,316	1,316	1,156	1,156	1,101	1,101	1,211	1,211
Chile	177	178	115	114	180	180	184	184	126	126
Other	17	52	—	58	18	66	—	49	—	39
Total	1,549	1,786	2,101	2,159	1,885	1,933	2,050	2,099	1,957	1,996
Europe:										
European Economic Community:										
Belgium-Luxembourg	648	905	771	1,084	1,727	2,107	1,856	2,185	1,800	2,215
France	399	644	441	710	1,241	2,002	1,200	1,924	1,900	2,070
Germany (West)	98	4,203	119	4,812	134	5,508	110	5,161	100	4,730
Italy	3,476	4,729	4,674	5,837	5,625	7,612	6,420	7,260	7,800	8,930
Netherlands b/	930	2,447	1,179	3,187	1,585	4,171	1,500	3,986	1,500	3,371
Total EEC	5,551	12,928	7,184	15,630	10,312	21,400	11,086	21,116	13,100	21,316
Germany (East)	—	—	—	—	28	28	133	268	121	121
Norway	35	58	10	17	10	17	55	93	150	164
Portugal	21	67	39	125	71	229	65	163	50	105
Romania	—	—	—	—	44	44	134	134	56	56
Spain	227	228	766	766	1,405	1,406	1,407	1,407	1,377	1,377
Sweden	820	820	725	725	875	875	991	991	870	870
Yugoslavia	420	420	414	414	405	404	472	472	558	558
Other	530	753	386	607	398	615	225	448	200	390
Total Other Europe	2,053	2,346	2,340	2,654	3,236	3,818	3,482	3,976	3,382	3,641
Asia:										
Japan	6,617	6,617	6,467	6,467	6,064	6,064	6,515	6,515	7,490	7,491
Other:										
Total	18	63	11	27	28	43	18	17	7	11
Grand total	20,611	34,969	23,026	38,413	27,448	47,078	29,268	47,970	31,996	50,182
Percent metallurgical of total exports	58.9		59.9		58.3		61.0		63.8	

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Appendix table 1. Estimated End Use of U. S. Bituminous Coal Exports, by Countries, in Thousand Short Tons, 1961-70 continued--
Part II. 1966-1970

Destination	1966		1967		1968		1969		1970	
	Metallurgical use	Total Exports	Metallurgical use	Total Exports	Metallurgical use	Total Exports	Metallurgical use	Total Exports	Metallurgical use	Total Exports
North America:										
Canada	6,000	15,829	5,546	15,269	6,978	16,748	6,274	16,800	6,900	18,673
Mexico	53	53	62	62	75	75	116	116	173	173
Other	—	5	—	8	—	4	—	4	—	4
Total	6,053	15,887	5,608	15,339	7,053	16,827	6,390	16,920	7,073	18,850
South America:										
Argentina	663	663	590	590	441	441	477	477	596	596
Brazil	1,739	1,739	1,735	1,735	1,787	1,787	1,843	1,843	2,020	2,020
Chile	156	156	156	193	230	306	240	518	275	275
Other	—	55	—	44	—	35	—	31	—	29
Total	2,558	2,613	2,481	2,562	2,458	2,569	2,560	2,869	2,891	2,920
Europe:										
European Economic Community:										
Belgium-Luxembourg	1,841	1,841	1,422	1,422	1,052	1,052	943	943	1,881	1,881
France	1,559	1,574	1,250	2,131	1,030	1,459	2,050	2,253	3,060	3,346
Germany (West)	150	4,894	89	4,694	71	3,785	100	3,451	316	5,022
Italy	6,946	7,805	5,150	5,816	4,000	4,254	3,472	3,679	3,950	4,205
Netherlands[b]	1,230	3,165	2,000	2,235	1,491	1,491	1,623	1,623	2,112	2,112
Total EEC	11,726	19,279	9,911	16,298	7,644	12,041	8,188	11,949	11,319	16,566
Germany (East)	156	156	77	77	101	101	87	87	396	396
Norway	200	220	220	246	305	305	248	248	192	192
Portugal	60	121	86	86	—	—	16	16	15	15
Romania	84	84	—	—	83	83	72	72	70	70
Spain	1,195	1,195	1,012	1,012	1,480	1,480	1,825	1,825	3,153	3,153
Sweden	951	951	813	813	761	761	668	668	764	764
Yugoslavia	596	596	532	532	436	436	141	141	225	225
Other	100	385	100	306	100	195	45	82	69	123
Total other Europe	3,342	3,708	2,840	3,072	3,266	3,361	3,102	3,139	4,884	4,938
Asia:										
Japan	7,791	7,791	12,226	12,226	15,822	15,822	21,367	21,367	27,601	27,601
Other:										
Total	5	24	4	13	5	17	—	2	—	33
Grand total	31,475	49,302	33,070	49,510	36,248	50,637	41,607	56,246	53,768	70,908
Percent metallurgical of total exports	63.8		66.8		71.6		74.0		75.8	

Appendix table 1. Estimated End Use of U.S. Bituminous Coal Exports, by Countries, in Thousands of Short Tons, 1961-70
continued--

Note: Estimates made for coking coal imported by several smaller producing countries, owing to insufficient information, are included in "other."

a/ Exports for metallurgical use for 1965 based on percentage relationship of known consumer requirements, in absence of specific official reporting; uses in some countries estimated from authoritative base data.

b/ Includes some tonnage transshipped to other undesignated European countries.

Source: Compiled by the Coal Export Staff, Division of Fossil Fuels, Bureau of Mines, from official data published by importing countries, and information reported by the Bureau of Census, coal exporters, railways, and coal producers.

Appendix table 2. Japan's Long-Term Contracts for Coking Coal with the United States

(In thousands of long tons)

Fiscal year	Steel								Others					
	Yawata Steel	Fuji Steel	Nippon Kokan	Kawa-saki Steel	Sumi-tomo Metal	Kobe Steel	Nisshin Steel	Sub-total	Mitsu-bishi Chem.	Mitsui Coke	Osaka Gas	Toho Gas	Sub-total	Grand Total
1969......	1,325	1,220	1,155	1,100	670	550	220	6,400	80	25	70	90	265	6,665
1970......	1,820	1,670	1,320	1,300	880	640	260	7,940	100	40	70	100	310	8,250
1971......	2,175	2,025	1,470	1,560	1,090	810	340	9,470	90	40	70	100	300	9,770
1972......	2,240	2,090	1,500	1,605	1,135	820	370	9,760	100	40	70	100	310	10,070
1973......	2,325	2,175	1,520	1,650	1,155	845	360	10,040	100	40	70	100	310	10,350
1974......	2,325	2,175	1,520	1,650	1,155	845	360	10,040	100	40	70	100	310	10,350
1975......	2,325	2,175	1,520	1,650	1,155	845	360	10,040	100	40	70	100	310	10,350
1976......	2,325	2,175	1,520	1,65[illegible]	1,155	845	360	[illegible]	100	40	70	100	310	10,350
1977......	1,500	1,450	1,170	900	595	405	310	6,330	100	40	70	100	310	6,640
1978......	1,500	1,450	1,170	900	595	405	310	6,330	100	40	70	100	310	6,640
1979......	1,500	1,450	1,170	900	595	405	310	6,330	100	40	70	100	310	6,640
1980......	1,500	1,450	1,170	900	595	405	310	6,330	100	40	70	100	310	6,640
1981......	1,225	1,175	1,070	700	420	280	260	5,130	100	40	70	100	310	5,440
1982......	850	800	650	700	420	280	260	3,960	100	40	70	100	310	4,270
1983......	850	800	650	700	420	280	260	3,960	100	40	70	100	310	4,270

Source: H. Horie, ed., Statistical Analysis, p. 33.

Appendix table 3. Japan's Long-Term Contract Volumes for Australian Coal by Brands, Years, and Consumers

(In thousands of long tons)

	Fiscal year										
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978 - 83[a]	1984
Coal Cliff.......	750	750	1,250	1,500	--	--	--	--	--	--	--
South Bulli......	880	1,200	1,400	1,400	1,400	--	--	--	--	--	--
Huntley..........	300	300	--	--	--	--	--	--	--	--	--
Wollondilly......	3,050	3,000	3,000	3,000	3,000	--	--	--	--	--	--
Moura............	3,500	3,500	3,500	4,500	4,500	4,500	4,500	4,500	4,500	--	--
Blackwater.......	1,750	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	--	--
Goonyella........	--	--	2,500	4,000	4,000	4,000	4,000	4,000	4,000	4,000	--
Peakdowns Highway	--	--	--	1,500	3,000	3,000	3,000	3,000	3,000	3,000	--
South Blackwater.	--	790	960	1,000	1,050	1,050	1,150	1,000	1,000	1,000	1,000
Liddell..........	1,330	1,330	1,330	1,330	1,330	--	--	--	--	--	--
Newdell..........	1,650	1,000	1,000	1,000	1,000	--	--	--	--	--	--
Newstan Borehold.	600	600	600	600	600	--	--	--	--	--	--
Big Ben..........	1,500	1,000	1,000	1,000	1,000	--	--	--	--	--	--
Daiyon No. 1.....	650	300	300	300	300	--	--	--	--	--	--
Abersea..........	670	670	670	670	670	--	--	--	--	--	--
Total.........	16,630	16,840	19,910	24,200	24,250	14,950	15,050	14,900	14,900	8,000	1,000

a/ Tonnages given are annual figures.

Source: H. Horie, ed., Statistical Analysis, p. 48.

Appendix table 4. Japan's Long-Term Contract Volumes of All Canadian Coking Coals by Years and Brands

(In thousands of long tons)

Fiscal year	Vicary Creek Coal	Balmer Coal	Luscar Coal	Smoky River Coal	Fording River Coal	Stewart Coal	Total
1969...........	600	400	--	--	--	90	1,090
1970...........	650	5,150	1,000	1,500[a/]	--	135	8,435
1971...........	1,000	5,150	1,000	2,000	--	150	9,300
1972...........	1,000	5,150	1,000	2,000	3,000[a/]	150	12,300
1973...........	1,000	5,150	1,000	2,000	3,000	150	12,300
1974...........	1,000	5,150	1,000	2,000	3,000	150	12,300
1975...........	1,000	5,000	1,000	2,000	3,000	150	12,150
1976...........	1,000	5,000	1,000	2,000	3,000	150	12,150
1977...........	1,000	5,000	1,000	2,000	3,000	150	12,150
1978...........	1,000	5,000	1,000	2,000	3,000	--	12,000
1979...........	1,000	5,000	1,000	2,000	3,000	--	12,000
1980...........	1,000	5,000	1,000	2,000	3,000	--	12,000
1981...........	1,000	5,000	1,000	2,000	3,000	--	12,000
1982...........	--	5,000	1,000	2,000	3,000	--	11,000
1983...........	--	5,000	1,000	2,000	3,000	--	11,000
1984...........	--	5,000	1,000	2,000	3,000	--	11,000
1985...........	--	--	--	--	3,000	--	3,000
1986...........	--	--	--	--	3,000	--	3,000
Grand total....	13,300	75,750	15,000	29,500	45,000	1,275	179,825

a/ Figures show the volumes at seller's option. (Smoky River coal: 500,000 tons; Fording River coal: 1 million tons.)

Source: H. Horie, ed., Statistical Analysis, pp. 162.

Appendix table 5. Seven-Year U.S.S.R. Coal Contracts for Japan

(In thousands of metric tons)

	Fiscal year							
	1969	1970	1971	1972	1973	1974	1975	1975
Kuznetsky KJ-14 coal	900 (75)	900 (75)	900 (100)	900 (100)	1,000 (100)	1,000 (100)	1,000 (100)	6,600 (650)
Kuznetsky K-10 coal	1,100 (75)	1,100 (75)	1,100 (100)	1,150 (100)	1,250 (100)	1,350 (100)	1,450 (100)	8,500 (650)
Kuznetsky OS coal	350 (150)	350 (150)	400 (200)	500 (200)	500 (200)	500 (200)	500 (200)	3,100 (1,300)
Kuznetsky G-6 coal	380 (150)	380 (150)	500 (200)	500 (200)	500 (200)	500 (200)	500 (200)	3,260 (1,300)
Subtotal	2,730 (450)	2,730 (450)	2,900 (600)	3,050 (600)	3,250 (650)	3,450 (650)	3,550 (650)	21,460 (3,900)
Shakhtersky coal	200 (20)	200 (20)	200 (50)	200 (50)	200 (50)	200 (50)	200 (50)	1,400 (290)
Grand	2,930 (470)	2,930 (470)	3,100 (650)	3,250 (650)	3,450 (650)	3,550 (650)	3,650 (650)	22,860 (4,190)

Note: Parenthesized figures show the volumes at seller's option.
Contract prices of above coals are US$13.10 FOB for Kuznetsky KJ-14 coal, US $12.85 FOB for Kuznetsky K-10 coal, US$9.50 FOB for Kuznetsky OS coal, US$9.50 FOB for Kuznetsky G-6 coal, and US$9.30 FOB for Shakhtersky coal.

Source: H. Horie, ed., Statistical Analysis, p. 144.

ANNEX A-6. U.S. EXPORTS OF GRAINS, SOY-
BEANS, AND MEAL

CONTENTS

SUMMARY

U.S. exports of grains and soybeans and meals are expected to continue to grow through 1980 and 2000. This conclusion rests on the expectation that rich and poor countries alike will expand economic output and raise per capita income levels sharply in the next 30 years, with a consequent increase in consumption of livestock products. Success in achieving this objective should, in the long run, enhance the opportunities for gain from international specialization and trade, and therefore the export of agricultural products in which the United States has a natural advantage.

Most countries have an extremely limited natural capability for increasing production of agricultural commodities such as wheat, corn, and soybeans, in view of the soil and climatic requirements of those crops. The United States, on the other hand, has comparatively vast areas of fertile land, a temperate climate, and generally adequate water supplies for agricultural production. U.S. policies and programs for agricultural research, and for price and income stabilization, are expected to continue to provide the means and the incentives for increased production.

The possibility of major advances in genetic capacity of crops such as corn, wheat, and soybeans should not be ruled out, but U.S. export capability does not turn on such a breakthrough. Similar policies and programs in developing countries, as well as in other developed countries, are expected to continue to generate a moderate rate of gain in worldwide agricultural productivity.

Exports of food and feed grains, and of oilseeds and oilmeals, from the United States are projected to rise from 54.6 million short tons in 1969 to 81 million short tons in 1980, an increase of 48 percent. They are projected to be 120 million short tons in 2000, 120 percent more than in 1969 and 48 percent more than in 1980 (table 1).

Feed grains will account for the greatest gains in tonnage exported, rising from 20.7 short tons in 1969 to 33 million short tons in 1980 and 55 million short tons in 2000 (table 2). Soybeans will also add sharply to export tonnage, increasing to 25 and 40 million short tons by 1980 and 2000 (table 3). Wheat exports will probably not increase greatly and are projected in 1980 and 2000 at approximately the 1963-65 level (table 4). Wheat for feed could make up a substantially larger share of total grain exports in 1980 and 2000, however, if research on hybrid wheats, for example, were to be spectacularly more successful than similar work on corn, sorghum, grain, or soybeans. Larger wheat exports for feed would probably be offset by smaller U.S. feed grain exports.

The existing organizational structure of the U.S. grain exporting sector is characterized by a high degree of concentration. The structure of grain buying organizations -- both state controlled and private -- in principal grain importing nations, is also characterized by considerable concentration of decision-making. This applies especially to Japan, the U.S.S.R., and Eastern Europe, and to the countries of the European Economic Community (EEC). It also applies to developing countries which take some U.S. grain, especially to India, Pakistan, Indonesia, and the Philippines. This organizational concentration of buyers and sellers provides one of the essential conditions to the use of larger vessels in U.S. export trade.

Table 1. Total Grains:[a] U.S. Exports to Specified Areas, Projected to 1980 and 2000

(In millions of short tons)

Area	1963-65	1969[b]	1980	2000
Western Hemisphere.....	6.6	9.1	12.3	14.0
Western Europe:				
EEC...................	17.0	16.2	21.0	24.7
Other.................	4.9	4.4	8.3	12.0
Total................	21.9	20.6	29.3	36.7
Africa.................	3.5	1.4	4.2	4.7
Asia:				
Japan.................	7.7	13.1	23.1	49.1
South Asia............	8.6	3.6	2.8	3.0
Other.................	4.2	6.3	7.3	9.6
Total................	20.5	23.0	33.2	61.7
All other.............	2.6	.5	2.0	2.9
World total...........	55.1	54.6	81.0	120.0

a/ Feed grains, wheat and flour, soybeans and meal.
b/ 1969-70 marketing year; minor revisions may have been made since mid-1971.

Source: See tables 2, 3, and 4.

Table 2. Feed Grains: U.S. Exports to Specified Areas, Projected to 1980 and 2000

(In millions of short tons)

Area	1963-65	1969[a]	1980	2000
Western Hemisphere.....	2.5	3.3	4.0	5.0
Western Europe:				
EEC..................	10.9	6.8	9.3	9.7
Other................	3.1	1.8	3.0	4.0
Total................	14.0	8.6	12.3	13.7
Africa................	.5	.1	.4	.6
Asia:				
Japan.................	4.0	7.4	13.7	31.8
Other................	1.5	1.3	1.3	1.7
Total................	5.5	8.7	15.0	33.5
All other.............	--	--	1.3	2.2
World total...........	22.5	20.7	33.0	55.0

a/ 1969-70 marketing year; minor revisions may have been made since mid-1971.

Source: U.S. Department of Agriculture, Feed Grain Statistics through 1966, Economic Research Service Statistical Bulletin 410, September 1967, and supplements.
1980 and 2000 -- RRNA.

Table 3. Soybeans and Meal: U.S. Exports to Specified Areas, Projected to 1980 and 2000

(In millions of short tons)

Area	1963-65	1969[a]	1980	2000
Western Hemisphere........	1.3	2.5	3.3	3.8
Western Europe:				
EEC......................	3.8	7.3	10.0	13.3
Other....................	1.1	2.2	5.0	7.7
Total..................	4.9	9.5	15.0	21.0
Asia:				
Japan....................	1.6	3.1	4.4	11.8
Other....................	.4	1.1	1.6	2.7
Total..................	2.0	4.2	6.0	14.5
All other................	.3	.5	.7	.7
World total..............	8.5	16.7	25.0	40.0

a/ 1969-70 marketing year; minor revisions may have been made since mid-1971.

Source: U.S. Department of Agriculture, U.S. Fats and Oil Statistics, 1909-1965, Economic Research Service Statistical Bulletin 376, August 1966 and supplements.
1980 and 2000 -- RRNA.

Table 4. Food Grains (Wheat and Wheat Flour): U.S. Exports to Specified Areas, Projected to 1980 and 2000

(In millions of short tons)

Area	1963-65	1969[a]	1980	2000
Western Hemisphere......	2.8	3.3	5.0	5.2
Western Europe:				
EEC....................	2.3	2.1	1.7	1.7
Other..................	.7	.4	.3	.3
Total.................	3.0	2.5	2.0	2.0
Africa..................	3.0	1.3	3.8	4.1
Asia:				
Japan..................	2.1	2.6	5.0	5.5
South Asia.............	8.0	3.6	2.2	2.2
Other..................	2.9	3.9	5.0	6.0
Total.................	13.0	10.1	12.2	13.7
All other...............	2.3	--	--	--
World total.............	24.1	17.2	23.0	25.0

a/ 1969-70 marketing year; minor revisions may have been made since mid-1971.

Source: U.S. Department of Agriculture, Food Grain Statistics through 1967, Economic Research Service Statistical Bulletin 423, April 1968, and supplements.
1980 and 2000 -- RRNA.

I. AGRICULTURAL TECHNOLOGY AND POLICY IN RELATION TO U.S. GRAIN EXPORTS

Chronic excess production, accumulated surplus stocks, and excess capacity to produce have plagued U.S. agriculture for the past 50 years. This tendency toward excess capacity has increased over the past 20 years, largely as a result of technological developments with strong output-increasing effects, accompanied by a rising level of management skills among agricultural producers. It has occurred despite a fairly steady erosion of agricultural product prices in relation to unit costs of inputs purchased for farm operations, as shown by the ratio of the index of prices paid by farmers to prices received, published by the U.S. Department of Agriculture. This "parity index" declined from 80 in 1960 to 70 in November 1971, and will probably continue to decline similarly in the 1970's.

Productivity per man-hour on the farm has risen dramatically, as output has increased while the number of farmers and farmworkers has declined and capital investment has risen sharply. There is no mystery in this -- either on the farm or in the factory. The productivity of aggregate farm resources (inputs), or output per unit of total input, including short- and long-term capital inputs, has risen steadily, but at a less dramatic rate than labor productivity.

The consensus of scientists and economists with respect to agricultural developments in the next 10 to 30 years is that far greater output and higher resource productivity in U.S. and world agriculture are both feasible and probable. This is true despite growing concern over chemical pollution of the planet, clear

identification of agricultural chemicals as one source of pollution, and the probability that there are genetic limits to the yield per acre of corn, wheat, and other plants now grown on farms. Scientists do not generally believe, however, that these limits have yet been approached.

Continuing heavy public investment and the accelerating level of private investment that is being made in the development of agricultural technology should assure a new generation of inventions, discoveries, and practical applications between now and the year 2000, paralleling the developments of the past 50 years. Further, increased basic scientific research directed toward areas such as health and space may have important feedbacks or byproducts for agricultural research, perhaps accelerating the rate of output-increasing discoveries. This is in contrast to the situation 30 to 50 years ago, when Federal support for research was largely limited to agriculture, and where agricultural research byproducts were often valuable to sectors outside agriculture.

If we accept the judgment of American agricultural scientists that we have not reached and probably are not even near a plateau on output-increasing scientific developments for agriculture, then one can be confident of the ability of the United States to supply a portion of the larger grain and oilseed import requirements of the world in the next 30 years, and perhaps increase its market share.

Some persons, however, fear that maintenance of even a precarious ecological balance will require a reduction in the use of chemical fertilizers, pesticides and herbicides, and that this could have an important negative impact on agricultural production in the United States and the developing world, where the new technologies have just begun to show results.

Recent economic studies reported by the U.S. Department of Agriculture have indicated that fears of sharp reductions in output when use of certain agricultural chemicals is limited are not yet well grounded,

and that substitution of other inputs can substantially offset output reductions. In a Department of Agriculture symposium in 1971, experts presented a careful but preliminary analysis of what would happen to U.S. agricultural production if use of important pesticides and herbicides were restricted to ecologically tolerable levels.1/ The results included:

1. Banning the use of 43 million pounds of phenoxy herbicides, principally 2-4D and 2, 4, 5-T, on 62 million acres of crops would increase direct costs of production by some $290 million a year, or by 1.5 percent of the value of all crops. Substitute herbicides and additional cultural practices made up the principal added costs.

2. A 70 to 80 percent reduction in insecticide use could be accomplished without reducing agricultural output if harvested acreage were increased by 12 percent, which is about half the amount of land diverted from agricultural production annually under the various U.S. Government land retirement programs in recent years.

The returns from this type of analysis are not at all in by any means. Dr. Norman Borlaug, the Nobel prize-winning agricultural scientist, has argued that catastrophic declines in agricultural output and in world food supplies would flow from any limitation of the use of chemical fertilizers, pesticides, or herbicides. Preliminary USDA research does not appear to support this.

But if such declines were to occur, the ability not only of the United States but other countries to put large amounts of grains and oilseeds into world trade late in the 20th century could be severely limited, while the needs abroad would be greater. Clearly, some substitutes for presently used polluting pesticides and herbicides are available. Also, intensive research efforts are underway to expand our capability in biological

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1/ See U.S. Department of Agriculture, Economic Research Service, Economic Research on Pesticides for Policy Decision-Making, 1971.

control of insects and in safer chemicals. Even with limitations there would be substantial use of fertilizer, however.

In summary, any sharp changes in agricultural practices, with consequent reductions in output or even flattening of past yield trends, are not expected either in the United States or abroad by 1980 or 2000.

Agricultural Subsidies and Stabilization

U.S. Government price support and subsidy policies toward U.S. agriculture continue to stimulate production. In the 1960's, studies by Iowa State University and USDA suggested that U.S. agricultural prices were probably 20 percent above market equilibrium levels. This continues to be the case, although cost inflation may have closed the gap somewhat in recent years. Major changes made in the structure of Federal agricultural stabilization programs in 1965 provided the machinery by which reductions in subsidy levels for the major commodities, including wheat and corn, could be made, but political factors prevented serious progress in that direction through 1971.

The modification which could have become the medium for reducing subsidies was a reduction in the level at which market prices were supported from well above world market values to competitive world market price levels. However, the reduced price support levels were supplemented by direct Federal payments to farmers, based almost entirely on volume of production. Payments were also contingent, in some cases, upon idling of part of a farmer's crop acreage in order to reduce surplus supplies and stabilize prices.

With market prices of major farm commodities at or near competitive levels since the mid-1960's, the degree of production stimulation in Federal farm programs has been linked closely to the size of total Federal payments to farmers, and not to price support levels. If future legislation were to limit payments

to individual farmers to as little as $5,000 or $10,000 per farmer, incentives to produce on large farms would be reduced somewhat.

The present trend, however, is in quite the other direction. When programs of the type described were first established, Federal payments to feed grain producers were set just high enough to encourage them to divert an acreage large enough to avoid surplus production. In 1971, however, a significant production subsidy was added to feed grain payments. Subsidy payments to grain producers will be higher in 1972 than in any previous year, even though agricultural production continues to outrun requirements at home and abroad.

Largely for political reasons, payments to wheat producers have been substantially in excess of levels required simply to reduce plantings enough to hold back wheat surpluses, and thus included a large element of subsidy. In 1969, about half the Federal payments to wheat producers served the function of increasing the incentive to produce and were a direct subsidy; the remainder of these payments were required to get farmers to participate in acreage and production adjustment programs.

Soybeans present quite a different situation, with sharply rising demands and strong prices heading off any pressure for major Federal subsidy efforts.

In view of the long history of agricultural subsidies and price supporting and stabilizing efforts, and considering the still-potent political strength of farmers, the prospect of the Federal Government's withdrawing its substantial support either from agricultural research and education, or from stabilization of agricultural price levels, is considered remote. Even if government support were to be reduced, U.S. producers are now generally efficient enough to meet world competition. Further, land values in the most productive agricultural areas of the United States, which have been pushed to high levels by new technology and by Federal subsidies attached to land, represent a substantial capacity to absorb reductions in prices or subsidies,

through reduced capital values, without any serious risk to the level of agricultural output.

U.S. Foreign Aid Policy

Foreign aid policies of the United States will probably not be an important factor in the level of U.S. grain exports in the next 10 to 30 years. Foreign aid, especially Public Law 480 (the Food for Peace Program), has been important to the level of wheat, flour, vegetable oil, and rice exports for the past 15 years, but it has been a declining factor since the late 1960's. Beginning with the enactment of the Food for Peace Program in 1956, U.S. wheat exports, made on generous concessional terms principally to Asian countries, increased substantially. By the early 1960's, some two-thirds of total U.S. wheat exports of 15 to 18 million tons per year were made under provisions of that program. Soybean and feed grain exports, however, have never depended to any degree either upon the Food for Peace Program or other foreign aid, but have been almost entirely commercial sales.

By the middle of the 1960's, Congress had begun to harden the terms on which Food for Peace commodities were made available. The large shipments to India and Pakistan in 1965-67, the years of the most recent South Asia drought, were the last under the original soft currency provisions of the 1956 act. That drought also coincided with the introduction into Asia of new varieties of wheat and rice, developed in Mexico and at the International Rice Research Institute in the Philippines. Use of fertilizer and other chemicals was increased sharply in order to realize the genetic potential of the new seeds, culminating in what is now known as the "green revolution."

The combination of new technologies and a degree of price stabilization provided through government programs in a number of developing countries made it possible for the countries of South Asia to sharply reduce their grain imports beginning in 1968 and running through 1971. Pakistan had the earliest success, with

India and the Philippines close behind. By 1971, except for the dislocations associated with the India-Pakistan war, both India and Pakistan were nearly self-sufficient in grain. The Philippines became self-sufficient in rice in 1970, but as a result of crop diseases is expected to import rice in 1972. The long-range grain export projections of this report incorporate an assumption that most Asian countries except Japan will continue to make gains in food production which will keep their import requirements at relatively low levels.

Conventional U.S. foreign aid (loans, grants, and technical assistance), which has been in political difficulty in the Congress for the past 5 years, has never contributed substantially to U.S. commodity exports, and might actually have inhibited exports in the longer run through its effect on production in the recipient country. Thus the possibility of sharp reductions in U.S. foreign assistance financing, and of major structural changes in whatever U.S. foreign aid programs remain, do not have serious implications for U.S. agricultural exports. The same is true for the expected level of operation of development activities by international institutions such as the World Bank, although their aid to development of agricultural cutput could have an effect on import requirements of the developing countries.

The Food for Peace Program, which will continue to be of some importance to the level of commodity exports, is not in political difficulty. For example, when Congress repeatedly delayed and then for a time defeated the foreign aid appropriation in 1971, a joint resolution of the Congress made it clear that persons in the Agency for International Development who were associated with the administration of the Food for Peace Program (in cooperation with the Department of Agriculture) were to be exempted from any reduction or termination of aid funds. For the 1970's, and probably for a period after that, demands for emergency food aid at levels ranging as high as at the peak of the Food for Peace Program would probably be met for brief periods by the United States in view of the special feeling in the Congress for food aid as distinct from overall foreign assistance.

II. STRUCTURE OF THE U.S. GRAIN EXPORT INDUSTRY

Exportation of grain from the United States is highly centralized. Three international companies dominate the industry, another three or four companies handle substantial quantities, and perhaps six more are engaged in grain exporting but do not handle a significant percentage of total trade. The three principal companies are the Continental Grain Company, New York; Cargill, Inc., Minneapolis; and Bunge Corporation, operating in New York but with world headquarters in Buenos Aires. Louis Dreyfuss Corporation, Garnac Grain Company, Cook and Company, and several grain cooperatives are also important in the U.S. grain trade, as are the Japanese trading companies, Mitsubishi and Mitsui.

The three dominant companies probably handle two-thirds of all the grain exported, but this figure is not actually known and varies from year to year. The other companies named handle nearly all the remainder.

Some experienced observers of the U.S. and world grain trade believe that the number of companies handling grain in world trade will be reduced during the next decade, as certain companies succeed financially while others do not, acquire extremely large shares of the market, and assert heavy competitive pressure worldwide. Yet there are no clear indications of this, and the existing structure is much like it was 20 years ago.

There has been some movement in the other direction in recent years in the United States, with several additional companies entering into the exporting of grain. Cook and Company was principally a cotton

exporter 10 years ago, but as cotton exports sagged, Cook expanded its grain activities during the 1960's to become one of the top six in volume of exports. Mitsui and Mitsubishi are dominant Japanese firms, and are highly diversified. They have entered the grain picture in the United States in the past 15 years as exports to Japan and other Asian countries increased in the 1960's, but they now also export to other markets.

The existing organizational structure of the grain exporting industry appears adaptable to the use of larger vessels. Trade sources indicate that there has been a significant movement in recent years toward the use of larger vessels for grains, and to loading such vessels in many cases with several grains and oilseeds bound for one or two destinations. There is an increasing tendency to maintain a continuous flow of commodities and to provide some storage in or near import markets in order to make effective use of vessels.

Countries of the EEC, other Western European countries, and Japan, all of which have taken the largest tonnages of each grain in past years, are generally expected to increase their imports in 10 and 30 years. These increased tonnages will make the loading of large vessels for single ports or countries more feasible than it now is. Some movement toward long-term contracting between exporting and importing nations also facilitates the shift to larger vessels.

It is not of decisive importance to the development of grain handling vessels and facilities of large size whether or not the number of companies exporting grain decreases or increases in the 1970's or 1980's, provided there is not a high degree of proliferation among a large number of firms. If today's three leading companies become two, or if some of today's largest companies absorb some smaller ones, their capabilities would not be changed decisively.

With some 56 million tons of all grains exported in 1969, 81 million tons projected for export in 1980 and 120 million tons in 2000, volumes are large enough

to accommodate several large companies. As shown in table 5, some two-thirds of all these exports are projected to be loaded out of gulf ports in 1980, and more than two-thirds out of gulf ports in 2000. This concentration on the gulf should facilitate the use of larger ships.

Table 5. All Grains: U.S. to Foreign Port Zones, Projected to 1980 and 2000
(In millions of short tons)

Foreign zones	U.S. zones						
	1 NA	2 SA	3 Gulf	4 Calif.	5 N. Pac.	6 Lakes	Total
1980							
1. Canada						1.5	2.0[a]
2. Atlantic-Carib.	.2		4.1		.1	.2	4.6
3. South America-Pacific			.5		.1		.6
4. South America-Atlantic			1.6				1.6
5. Northwest Europe	3.1	.4	13.4			4.5	24.9
6. Med.-Southwest Europe	.5		7.0			.2	7.7
7. Other Mediterranean	.5		3.0			.3	3.8
8. East Europe			.9				.9
9. Africa-Atl. and Indian Ocean			2.3				2.3
10. Mideast			.3				.3
11. South Asia			1.9		.9		2.8
12. Southeast Asia	.1		2.9	.6	2.8		6.4
15. Japan			16.5	1.6	4.6	.4	23.1
Total	4.4	.4	54.4	2.2	8.5	11.1	81.0
2000							
1. Canada						6.8	2.3[a]
2. Atlantic-Carib.	.2		4.7		.1	.2	5.2

continued--

Table 5. All Grains: U.S. to Foreign Port Zones, Projected to 1980 and 2000
continued--

(In millions of short tons)

Foreign zones	U.S. zones						
	1 NA	2 SA	3 Gulf	4 Calif.	5 N. Pac.	6 Lakes	Total
3. South America-Pacific....			.6		.2		.8
4. South America-Atlantic..			1.7				1.7
5. Northwest Europe........	3.5	.6	15.1			5.2	28.9
6. Med.-Southwest Europe...	.6		11.0			.2	11.8
7. Other Mediterranean.....	.5		4.3			.3	5.1
8. East Europe.............			1.0				1.0
9. Africa-Atl. and Indian Ocean..................			2.6				2.6
10. Mideast................			.5				.5
11. South Asia.............			2.0		1.0		3.0
12. Southeast Asia.........	.1		3.5	1.0	3.4		8.0
15. Japan..................			39.6	3.5	5.0	1.0	49.1
Total..................	4.9	.6	86.6	4.5	9.7	13.7	120.0

a/ Estimated transshipments from Canada to Northwest Europe added to total for Foreign Port Zone No. 5.

III. STRUCTURE OF GRAIN-BUYING ENTITIES IN IMPORTING COUNTRIES

Agencies procuring grain for use in the largest grain importing countries of the world are already relatively large and centralized. This facilitates acquisition of relatively large cargoes and the use of increasingly large vessels.

Japan will be the largest single purchaser of grain in world trade in the next three decades and the largest single customer of the United States. For many years, Japan has purchased her wheat requirements through the Food Agency, a government bureau which buys at world market prices from Japanese firms that have procured the grain by various means, and which sells or consigns needed grains to flour millers. The Food Agency thus serves as the collector of extremely large government revenues arising out of low acquisition prices for grain in world markets and the high grain price level maintained internally to protect Japanese rice producers.

For the past 5 years, there have been indications that this method of procurement would be changed to give more autonomy to the companies actually using the imported grain in food manufacturing. However, since Japanese farmers will be protected for many years ahead, and since the Food Agency performs an important tax collection function in the Japanese system which would have to be performed elsewhere in the marketing system if its functions were terminated or changed, the system continues. Whatever changes might be made in Japan's procurement system are not expected to be adverse to the use of large vessels if they offer financial economies in the 1980's and 1990's.

The Food Agency does not procure feed grains and oilseeds, but Zenkoren -- a super-cooperative -- now imports more than half of Japan's total requirements. The introduction of "kombimats" -- large port elevator complexes including flour mills, feed mills, and oilseed crushing facilities -- during the last 5 to 6 years has enabled Japan to use large vessels for the first time. More of these are said to be planned. Japan, however, is one of the few remaining important markets buying substantial quantities of grain in 13,000 to 14,000 ton cargoes.

Grain purchasing is also relatively concentrated in Europe. Great Britain now has only half a dozen large flour millers and feed compounders. Most of the wheat, coarse grains, and oilseeds required by Dutch and Belgian millers and compounders is purchased by a few brokers and resold to the Dutch and Belgian processing firms. Only three or four firms are engaged in importation of substantial quantities of grain into the port of Hamburg for use by northern German millers and compounders. Smaller companies are also involved, but the bulk of imports are concentrated in a few hands.

Clearly, the business structure for acquisition of imports in the planned economies of Eastern Europe and the U.S.S.R. is such as to encourage the use of larger vessels when the volume of imports is large enough to warrant such.

Thus for the major import markets, corporate or state structures for acquiring grain are already congenial to the purchase of relatively large cargoes of various types of grain. Since purchasers are typically involved in the acquisition of several types of grain and oilseeds, loading a ship partly with corn, partly with wheat, and partly with soybeans is practical.

However, other economic and institutional variables are also relevant to the decision to employ larger vessels. These are discussed in the ocean transport section of the Deepwater Port Study.

IV. FACTORS GOVERNING FOOD AND FEED GRAIN CONSUMPTION PATTERNS

The term "feed grains" applies to grains which principally are used as feed for livestock, i.e., meat and dairy cattle, hogs, and poultry. The grains so classified in this study are also defined as "coarse" grains. They include corn, grain sorghum, oats and barley. In varying degrees they also are used for direct human consumption, for processing into other products for human consumption, and for industrial purposes. Thus, corn becomes corn flour, corn syrup, and cornstarch. Barley is used in brewing, and oats become a breakfast cereal.

In 1965 it was estimated that of total world consumption of 498 million metric tons of coarse grains, 122 million or roughly one-quarter were used for food, 293 million or roughly 60 percent were used for feed, and the balance was for other uses. However, 92 percent of coarse grain consumption for food took place in less developed countries (LDC's) and in the so-called Central Plan countries (U.S.S.R., Eastern Europe, and the People's Republic of China). Eighty percent of the consumption of coarse grains in the developed countries was as livestock feed (appendix table 1).

Food grains, mainly wheat and rice, are used primarily for human consumption, but may also be used as livestock feed, depending principally on relative prices of such grains, coarse grains, and other animal feedstuffs. On a worldwide basis, of a total consumption of 415 million tons of wheat and rice in 1965, 21 million tons were consumed as livestock feed. But 94 percent

of this consumption for feed purposes took place in the developed and Central Plan countries (appendix table 1).

Of the total world consumption of all grains for feed in 1965 of 314 million tons, 195 million were consumed in the developed countries, 90 million in the Central Plan countries, and only 30 million, or less than 10 percent, in the LDC's. Grains used for feed in the LDC's accounted for less than 11 percent of their total grain consumption. Consumption of grain for food in the LDC's accounted for 73 percent of total grain consumption in 1965, whereas in the developed countries it was approximately 20 percent (appendix table 1).

These comparisons of relative consumption of grains for feed and food purposes in the developed and less developed countries reflect what has become a fairly well-established phenomenon in human food consumption patterns, i.e., that at the lowest income levels diets consist almost entirely of grains and virtually no meat, but that as incomes rise consumption of meat increases and displaces human consumption of grain.

At the same time, however, the technology of livestock meat production shifts from mainly or entirely range and pasture feeding to feeding with grains and prepared feeds. Since anywhere from approximately 5 to over 15 pounds of grains and prepared feeds are required to produce 1 pound of meat for human consumption (the lower end of the range for poultry and the higher end for beef), total grain consumption increases with the shift away from human grain consumption to meat.

Variations in human consumption of meat and grain and in the consumption of grain for meat production at different levels of per capita income are shown in appendix tables 2 and 3, taken from one of several Department of Agriculture studies of world production, consumption, and trade in grains and other principal agricultural commodities completed during 1970 and 1971. These are identified and described in detail in the appendix.

There is a very high rate of elasticity of meat consumption per unit of increase in per capita income at the lower income levels, ranging from 3.41 at $75 annual per capita income to .55 at $350. As incomes increase beyond $350, consumption elasticity also increases. At per capita income levels of $100, $200, and $500, per capita meat consumption is approximately 10, 19, and 32 kilograms respectively. At $3,000 per capita income, per capita meat consumption is 113 kilograms. The latter corresponds roughly with per capita consumption in the United States.

At the $100 income level, per capita human consumption of meat and cereal grain combined is 166 kilograms, of which 156 kilograms are grain; at the $3,000 income level per capita consumption of the two food sources is 174 kilograms, of which 61 kilograms are grain. As annual income rises from $100 to $3,000, per capita consumption of meat rises from 10 to 113 kilograms, and the grain-meat ratio rises from 1.31 to 4.29. Thus the decline of approximately 100 kilograms in per capita human consumption of grain is accompanied by an increase in the consumption of meat of 100 kilograms, which requires the feeding of approximately 400 kilograms of grain to livestock. In other words, a quadrupling of the gross grain consumption is required to sustain the human diet at the $3,000 per capita income level compared with the $100 level.

Soybean meal or cake, which together with soybeans constitutes the third agricultural commodity category included in this study, is used primarily as animal feed. For this purpose it supplements, complements, and sometimes competes with coarse grains. It is one of several oilseed meals used for this purpose, including palm kernel, cottonseed, peanut, linseed, rapeseed, and sunflower seed meal. In addition, fish meal is used for animal feed.

Because soybean meal is used primarily as an animal feed, the markets for soybeans and soybean meal are substantially a function of changes in levels of aggregate and per capita production and consumption of meat and livestock products, in the same manner as are the coarse grains. Soybean meal may be exported directly

as such, or soybeans may be exported for the crushing and recovery of soybean oil and soybean meal in foreign markets. The form in which the export takes place is dependent on the availability of crushing capacity in the importing country.

V. U.S. GRAIN EXPORT PROJECTIONS

Introduction

Commodity Coverage

As used in this study, U.S. exports of grains refer to the sum of three commodity groups: (1) feed grains (corn, grain sorghums, oats and barley); (2) food grains (represented by wheat and wheat flour); and (3) soybeans and meal.

The Estimating Sequence

1. U.S. exports for the three commodity groups were projected to 1980 and 2000 on a global basis and by principal importing countries or areas.

2. Projections of exports by country or area were allocated to 12 foreign import zones and six U.S. port zones.

3. Exports from U.S. ports were allocated to various producing areas which normally supply grains for export and are expected to continue to do so.

Methods of Projection

For 1980, the problem was essentially one of selecting or deriving a set of estimates from those already at hand. Although a considerable number of studies focusing on the period 1975-85 were consulted, the USDA/AID studies on grains, oilseeds and meals discussed in the appendix were used as the benchmarks for

1980. These studies were the result of a large-scale, 4-year research project conducted by the Economic Research Service, USDA, for the Agency for International Development, using modern econometric analysis to achieve an approximate equilibrium of production, consumption, prices and trade on a worldwide basis under several different sets of assumptions.

For 2000, existing studies provided only limited guidance, so a new set of estimates had to be developed for that year. It was necessary to extend the 1980 projections to the end of the century largely on the basis of projected increases in population and income, limited statistical analysis of the probable effect of these changes on grain production and consumption, and the advice of commodity experts who are abreast of current trends and informed on factors likely to affect the demand for U.S. grains over the longer run.

Some Problems of Long-Range Economic Projections

Despite increasing use of economic projections as an aid to long-range planning, there continues to be considerable misunderstanding of their nature and use. Such projections are frequently termed "conditional forecasts" in the sense that they are to be regarded as approximations of what can be expected over the next one to three decades, if the underlying assumptions with respect to such variables as population, income, production, prices and government policies are substantially realized.

Although advanced statistical and econometric methods are being used in making long-range projections, the importance of certain basic assumptions can hardly be overemphasized. For example, in the USDA/AID study of grains (FAER No. 75), assumptions with respect to government policies in both exporting and importing countries and agricultural productivity in the LDC's are critical. Thus, under the Set I assumptions adopted here, U.S. net exports of coarse grains are projected at about 33 million short tons in 1980. But if agricultural productivity in the LDC's is assumed to accelerate by a factor of 0.4, the overall export projection would

drop to about 23 million tons. On the other hand, if agricultural productivity and economic growth were to slow by a factor of 0.3, projected U.S. coarse grain exports would rise to around 39 million tons.

In addition to the problems that beset long-range economic projections generally, the grains present special difficulties because of their substitutability as discussed in chapter IV.

The development of high-yielding, fertilizer-responsive, dwarf varieties of wheat and rice that can be grown in many parts of Asia also introduces a new but quite uncertain factor into the world grain picture. If those who predict great new advances of wheat and rice production in the less developed countries are most nearly correct, export prospects for the major wheat suppliers (United States, Canada, Australia and France) will diminish. But if those who stress increasing limitations on the spread of the Green Revolution are most nearly right, wheat export prospects for developed countries appear to be good, provided financing is available.

Government policies affecting the production and export of grain -- which could change rapidly and radically but seldom do -- are certain to play a major role. The extent to which such countries as the United States and those of the EEC will continue to bear the heavy costs of export subsidies provides one example. Even world politics enters the picture. In the early 1960's, U.S. exports of wheat and wheat flour to the UAR were around 50 to 60 million bushels a year. Now they have dropped to zero, but are more than offset in 1971-72 by exports of feed grains to the U.S.S.R.

The changing patterns of world politics are not necessarily decisive factors in the level of U.S. grain exports. Our principal competitors for world grain markets -- Canada, Australia, Argentina, and France -- have extremely limited agricultural capabilities compared with the United States. In the short run, gains those countries make in exports to Russia or China, for instance, reduce their capacity to ship grain to their

older customers. The United States can and does take advantage of such opportunities, exporting stored reserves and a broader mix of available commodities. And if the United States moves into smaller markets now served by our weaker competitors, they are sure to take over some of our traditional markets, since they lack both the storage capacity and the financial ability to hold large grain reserves for long periods.

Feed Grains -- Global and Area Projections

Note on Coverage

Feed grain projections center on corn and grain sorghum, which typically account for about 95 percent of total U.S. feed grain exports. In some studies exports of corn have been projected separately from sorghums, but this has not been done here because of the wide fluctuations in sorghum exports and because of the fact that the two grains are close substitutes in most animal rations. The rapid expansion of sorghum and corn production in the Central and Southern Plains has provided another source of grain for the feedlots of Colorado, New Mexico, Arizona and California. When production runs ahead of domestic demand in these areas exports are large, going primarily to Japan, with a considerable volume moving through the California ports. When local demand in feeding areas of the Great Plains claims these supplies, there is considerable substitution of Midwest corn that moves through the gulf ports to Japan as well as to Europe.

Projections for 1980

The USDA/AID projection of 30 million metric tons (33 million short tons) for total 1980 U.S. coarse grain exports was accepted (see appendix table 8). Area distributions were accepted substantially for Western Europe and for Asian countries other than Japan, where a considerable downward adjustment was made in anticipation of gains by Australian and possibly by other Asiatic sources in the world's feed grain trade (see tables 3 and 6).

Table 6. Feed Grains: Exports from U.S. to Foreign Port Zones, Projections to 1980 and 2000

(In millions of short tons)

Foreign zones	U.S. zones						
	1 NA	2 SA	3 Gulf	4 Calif.	5 N. Pac.	6 Lakes	Total
1980							
1. Canada....................						2.0	1.0[a/]
2. Atlantic-Carib...........			1.6				1.6
3. South America-Pacific....			.3				.3
4. South America-Atlantic...			.1				.1
5. Northwest Europe.........	1.7		4.8			2.5	10.0
6. Med.-Southwest Europe....	.2		3.1				3.3
7. Other Mediterranean......	.1		1.0				1.1
8. East Europe..............			.4				.4
9. Africa-Atl. and Indian Ocean...................			.2				.2
10. Mideast..................			--				--
11. South Asia...............			.6				.6
12. Southeast Asia...........			.4		.3		.7
15. Japan....................			12.3	1.4			13.7
Total....................	2.0	--	24.8	1.4	.3	4.5	33.0
2000							
1. Canada....................						2.5	1.0[a/]
2. Atlantic-Carib...........			1.9				1.9

continued--

Table 6. Feed Grains: Exports from U.S. to Foreign Port Zones, Projections to 1980 and 2000 continued--

(In millions of short tons)

Foreign zones	U.S. zones						
	1 NA	2 SA	3 Gulf	4 Calif.	5 N. Pac.	6 Lakes	Total
3. South America-Pacific....			.4				.4
4. South America-Atlantic....			.2				.2
5. Northwest Europe.........	1.8		4.9			2.5	10.7
6. Med.-Southwest Europe....	.2		4.3				4.5
7. Other Mediterranean......	.1		1.9				2.0
8. East Europe..............			.5				.5
9. Africa-Atl. and Indian Ocean..................			.3				.3
10. Mideast..................			--				--
11. South Asia...............			.8				.8
12. Southeast Asia...........			.5		.4		.9
15. Japan....................			28.6	3.2			31.8
Total....................	2.1		44.3	3.2	.4	5.0	55.0

a/ Estimated transshipments from Canada to Northwest Europe added to total for Foreign Port Zone No. 5.

The case of Japan demands special attention. Meat consumption and production (and hence imports of feed grains) in that country have been far below the levels that would correspond to its remarkable increases in national income and consumer demand. Since about 1960 Japan has followed a deliberate policy of increasing domestic food supplies per capita, particularly high-energy foods, through a combination of expanded domestic production and larger imports of raw food materials, notably feed grains, wheat, oilseeds and sugar.

The Japanese Food Agency has extremely broad powers to control food prices, food production and imports. With respect to imports Japan is making a considerable effort to diversify its sources, to rely less on the United States as a supplier of feed grains and more on Southeast Asia, Australia, New Zealand and South America. This policy was termed a "Pacific strategy" in a USDA study on Japan,1/ and implies considerably lower levels of feed grain imports than a "Western strategy," which would allow consumption of livestock products to match rising consumer demand and which would require a liberal trade policy that would be especially favorable to the United States as an efficient, low-cost exporter of feed grains.

There is no way to know just how Japan's food strategy will evolve, but a reasonable assumption is that it will lean in the direction of a Pacific strategy over the next decade. But from about then until the end of the century, a gradual shift to a Western strategy seems likely, because of increasing pressure to meet rising consumer demands for meat and other livestock products.

Yet, with Japan accounting for such a large share of U.S. grain and oilseed exports, it is important to recognize that there are some uncertainties regarding Japan's total feed grain demand, and the development of

1/ U.S. Department of Agriculture, Japan's Food Demand and 1985 Grain Import Prospects, Foreign Agricultural Economic Report No. 53, June 1969.

alternative sources of supply. Japan's recent economic success, her continuing preoccupation with economic growth, and the close Japanese partnership between government and business in working toward basic economic objectives lend credence to the relatively high import projections shown in this annex.

The USDA/AID study on grain[1/] indicated that feed grain import requirements in 1980 would be around 18 million net tons. Continuation of recent trends in imports from non-U.S. sources would appear to add up to about 4 million tons by 1980, so a figure close to 14 million was adopted for U.S. exports in 1980.

Despite this lower projection for exports to Japan, the total export level of 33 million tons was maintained, by allowing for exports to Canada, Africa and Eastern Europe, for which no allocations were made in the USDA study. Exports to Canada tend to be a function of feed deficits in that country, which have averaged about 1 million short tons a year recently. That figure was used as the projection. The allowances for Africa and Eastern Europe were made on the basis of recent Census data on shipments to port zones in those areas. A result was to reduce somewhat the USDA/AID projections for Latin America, which seem on the high side in the light of more recent export levels.

Projections for 2000

The basic approach for this more distant year was to estimate total feed grain requirements in the major importing countries and areas. From RRNA projections of income, population and income per capita (annex A-1), estimates were made of per capita meat consumption, total meat consumption, domestic meat production and feed grain requirements for all importing countries. This was done by utilizing the USDA data with respect to the relationship between per capita income and per

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1/ U.S. Department of Agriculture, World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, December 1971.

capita meat consumption, the likely degree of self-sufficiency in meat production, and the ratio of grain requirements to meat production (see the appendix and table 7).

Starting with the requirements for Europe, and giving the United States the same share of those requirements as in the USDA/AID projections for 1980, yielded exports of about 18 million short tons. However -- on the basis of studies dealing with the Common Market and discussions with commodity experts -- this figure was reduced to a little over 14 million short tons to allow for continued progress toward a higher degree of self-sufficiency within the EEC and increased competition from other areas such as Argentina.

For Japan it was assumed that the shift to a so-called Western strategy would be completed by the year 2000. This implies high consumption levels for livestock accompanied by large feed grain requirements. The estimated per capita product consumption and imports of grain presented in the USDA Japanese study for 1985 under the Western strategy assumption provides the basis for projecting these requirements. These estimates were multiplied for RRNA population projections for Japan in the year 2000, resulting in total feed grain requirements of about 50 million short tons, practically all of which would have to be imported.

Under the essentially competitive conditions of recent years, about 55 percent of these requirements would be provided by the United States (that is, about 27.5 million tons). However, we have assumed that about 65 percent of Japanese imports would be from the United States, or about 32 million tons. This is not an unreasonably high proportion, in view of the fact that the greatest increase in Japan's grain needs will be feed grains, for which the United States is and will be by far the world's principal supplier. Further, U.S. shipments actually exceeded that share in 1964-66.

This estimate of a relatively high share in the Japanese grain market in 2000 is also bolstered by a

Table 7. Projected Feed Grain Consumption in the United States, Canada, Selected European Areas, and Japan, 1970 (Estimated) and Projected 1980, 1990, and 2000

Year and item	United States	Canada	EEC	EFTA	Other OECD	Japan
1970						
GNP per capita (1968) ($)	4,380	3,010	2,040	1,920	810	--
Grain-meat ratio (kg. grain/kg. meat)	6.94	6.94	4.19	4.40	5.67	5.49
Meat consumption per capita (kg.)	100.0	87.4	66.5	68.8	27.1	9.6
Total meat production (1,000 m.t.)	20,478	1,854	11,541	6,126	1,525	--
Total feed grain consumption (1,000 m.t.)	142,117	12,867	48,357	26,954	8,647	--
1980						
GNP per capita ($)	6,180	4,640	3,570	2,760	1,450	--
Grain-meat ratio (kg. grain/kg. meat)	6.94	6.94	4.30	4.50	6.00	6.30
Meat consumption per capita (kg.)	110.0	98.2	74.4	76.8	32.1	16.9
Total meat production (1,000 m.t.)	25,488	2,459	13,805	7,306	1,969	--
Total feed grain consumption (1,000 m.t.)	176,887	17,065	59,362	32,877	11,814	--
1990						
GNP per capita ($)	7,860	5,930	5,270	4,120	2,400	--
Grain-meat ratio (kg. grain/kg. meat)	7.00	7.00	4.64	4.84	6.25	--

continued--

Table 7. Projected Feed Grain Consumption in the United States, Canada, Selected European Areas, and Japan, 1970 (Estimated) and Projected 1980, 1990, and 2000 continued--

Year and item	United States	Canada	EEC	EFTA	Other OECD	Japan
Meat consumption per capita (kg.)..........	110.0	105.0	79.7	84.4	36.6	--
Total meat production (1,000 m.t.)..........	29,207	3,133	15,804	8,619	2,435	--
Total feed grain consumption (1,000 m.t.).	204,449	21,931	73,331	41,716	15,219	--
2000						
GNP per capita ($).....	10,500	7,500	7,470	5,870	4,000	--
Grain-meat ratio (kg. grain/kg. meat).......	7.00	7.00	4.91	5.11	6.31	--
Meat consumption per capita (kg.)..........	110.0	110.0	84.6	92.0	40.3	--
Total meat production (1,000 m.t.)..........	32,988	3,919	17,889	10,034	2,872	--
Total feed grain consumption (1,000 m.t.).	230,916	27,433	87,835	51,274	18,122	--

Note: Total feed grain consumption was derived by first multiplying given meat consumption per capita times population to estimate total meat consumption. Total meat consumption times the assumed constant self-sufficiency index (FAER No. 63, Tables 61, 62) yielded total meat production, which when multiplied by the grain-meat ratio provided total feed grain consumption.

Source: Grain-meat ratio and meat consumption per capita -- U.S. Department of Agriculture, Growth in World Demand for Feed Grains, Foreign Agricultural Economic Report No. 63, July 1970. GNP per capita and population estimates -- U.S. Deepwater Port Study, Annex A-1.

judgment that Australia and Thailand, the two prospective major exporters of coarse grains, will not be able to respond with export supplies of the magnitude required by Japan, and that increased consumption of meat in those two countries and other Asian countries, including Korea and Taiwan, will be absorbing much of the expected expansion in grain production.

These projections also involve an assumption that Japan will continue to maintain its very high degree of meat self-sufficiency, even at sharply higher levels of consumption. Even allowing for increased meat imports, a high proportion of the rising domestic demand for meat would be produced at home and would require a large expansion in grain imports.

On the basis of the foregoing, U.S. feed grain exports to Western Europe and Japan combined would total about 46 million net tons. In exports to other areas only a moderate increase of perhaps 2.5 million tons above the 1980 projection of 6.5 million is estimated, bringing total U.S. feed grain exports in 2000 to 55 million tons. This total is also consistent with an extrapolation of a long-run trend drawn through actual exports during 1955-69 and the 1980 projection of 33 million tons.

Food Grains -- Global and Area Projections

Wheat and wheat flour are taken to represent the trade in food grains. Rice is so small in the U.S. grain export picture that it was not made the object of a separate analysis. In recent years rice has accounted for only about 7 percent of total U.S. food grain exports and for about 3 percent of all grain exports. Also, rice is the commodity whose trade is most likely to be affected adversely by the Green Revolution.

Statistical analysis is less applicable to long-range projections for wheat exports than it is for coarse grains and soybeans. Major exporters, such as Canada and the United States, are able to influence the

volume of their exports through various combinations of export subsidies, credits, food aid and controls on production. Major importers, particularly the EEC, can reduce imports through various combinations of quotas, tariffs, and production subsidies to domestic growers. The still-debatable course of the Green Revolution is particularly important for the food grains. If it falters, export markets of the developed countries can be maintained and probably enlarged, through aid and easy credit. If it accelerates, these markets will shrink drastically, as has already occurred in 1970 and 1971.

Projections for 1980

As in the case of feed grains and soybeans, the 1980 projections here (tables 4 and 8) are fairly close to the projections under Set I assumptions in the USDA/AID study.1/ These are also consistent with key assumptions adopted by RRNA staff. First, the United States will maintain its fairly stable share in the traditional markets, except for Western Europe; this share averaged somewhat over 40 percent during the 1960's in markets including Latin America, Africa, Japan and Asia. In the latter area, continuation of concessional programs for South Korea and Taiwan is anticipated. Food aid shipments to India and Pakistan of the late 1960's will be sharply reduced from the 1960's, but a moderate average level of shipments is included in the projections to allow for periods of drought, floods, wars, or other emergencies.

Practically all expert opinion with respect to export prospects for U.S. wheat over the next decade center on maintaining total exports at around 20 million short tons a year. Some analysts think this goal will be difficult to achieve, while others believe that demands in the traditional markets such as Africa, Latin America and Japan will be strong, and that we may hold a considerable share of the Western European market, especially if the costs of the EEC agricultural program

1/ U.S. Department of Agriculture, World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, December 1971.

Table 8. Food Grains: Exports from U.S. to Foreign Port Zones, Projections to 1980 and 2000

(In millions of short tons)

Foreign zones	U.S. zones						
	1 NA	2 SA	3 Gulf	4 Calif.	5 N. Pac.	6 Lakes	Total
1980							
1. Canada....................						.5	a/
2. Atlantic-Carib...........	.2		2.2		.1	.2	2.7
3. South America-Pacific....			.2		.1		.3
4. South America-Atlantic...			1.5				1.5
5. Northwest Europe.........	.2		1.0			.5	2.2
6. Med.-Southwest Europe....	.1					.2	.3
7. Other Mediterranean......	.4		1.0			.3	1.7
8. East Europe..............							--
9. Africa-Atl. and Indian Ocean..................			2.1				2.1
10. Mideast..................			.3				.3
11. South Asia...............			1.3		.9		2.2
12. Southeast Asia...........			1.6	.6	2.5		4.7
15. Japan....................			.2	.2	4.6		5.0
Total....................	.9	--	11.4	.8	8.2	1.7	23.0
2000							
1. Canada....................						.5	a/
2. Atlantic-Carib...........	.2		2.3		.1	.2	2.8

continued--

Table 8. Food Grains: Exports from U.S. to Foreign Port Zones, Projections to 1980 and 2000 continued--

(In millions of short tons)

Foreign zones	U.S. zones						
	1 NA	2 SA	3 Gulf	4 Calif.	5 N. Pac.	6 Lakes	Total
3. South America-Pacific....			.2		.2		.4
4. South America-Atlantic...			1.5				1.5
5. Northwest Europe.........	.2		1.0			.5	2.2
6. Med.-Southwest Europe....	.1					.2	.3
7. Other Mediterranean......	.4		1.1			.3	1.8
8. East Europe..............							--
9. Africa-Atl. and Indian Ocean..................			2.3				2.3
10. Mideast.................			.5				.5
11. South Asia..............			1.2		1.0		2.2
12. Southeast Asia..........			1.5	1.0	3.0		5.5
15. Japan...................			.2	.3	5.0		5.5
Total....................	.9	--	11.8	1.3	9.3	1.7	25.0

a/ All U.S. wheat shipped to Canadian ports added to Northwest Europe total to allow for transshipments.

become excessive. The projected total of 23 million short tons in 1980 reflects some tendency towards optimism, and is about 8 percent above the USDA/AID projection under the Set I assumptions. Support for this optimism is provided by another study performed by the Outlook and Projections Branch of the USDA Economic Research Service, entitled "A View of Food and Agriculture in 1980."1/ In that study, wheat exports in 1980 were projected at 740 million bushels, or about 22.2 million short tons. In the event wheat exports substantially exceed that level because of increased feeding of wheat, coarse grain exports would be reduced almost proportionately and the effect on total grain shipments would be negligible.

Projections for 2000

The world trade outlook for wheat 30 years ahead is highly speculative. Some of the reasons for this have been noted above in connection with the 1980 projections.

However, the USDA/AID projections for 1980 clearly point to a flattening out of the U.S. wheat export curve within a range of 22 to 25 million tons. This would occur unless marked increases in agricultural production in the LDC's forced a contraction in U.S. exports to around 16 million tons, or unless the Green Revolution collapsed, placing increased demands on world supplies.

A leveling out of wheat exports is not inconsistent, however, with some gain in exports to the traditional markets. So a small increase is projected, from 23 million tons in 1980 to 25 million in 2000 (tables 4 and 8). Distribution among countries and areas follows the pattern used for 1980. However, it should be emphasized that any projection within the 20 to 25 million ton range for wheat exports is plausible, and would

1/ In U.S. Department of Agriculture, Economic Research Service, Agricultural Economic Research, vol. 22, no. 3, July 1970.

not significantly affect the overall tonnage or port distributions for grains as a whole.

Soybeans and Meal -- Global and Area Projections

Projections for 1980

The starting point for projections to 1980 was the USDA/AID study, World Supply and Demand Prospects For Oilseeds and Oilseed Products in 1980,1/ under Set I assumptions -- continuation of present production and trade policies, allowing for moderate gains in productivity in the developing countries.

This report, though technically very competent, was not as directly applicable to our projections as the companion study of grains. First, the export projections are in terms of total oilcakes and oil from all oilseeds rather than of the individual oilseeds. Second, there was no trade matrix for 1980 to provide a basis for country and area distributions.

Nevertheless, it was possible to use the projected percentage increase of U.S. exports in terms of oilcakes from the base period 1963-65 to 1980 as a first approximation of total exports of soybeans and soybean meal, which dominate U.S. exports of oilseeds and products. This gives a preliminary total export tonnage of about 22.5 million short tons of soybeans and meal, with the latter representing about 30 percent of total tonnage in line with recent experience.

However, rapid expansion of exports of soybeans and meal during the past several years -- together with large increases in crushing capacity, especially in Europe -- indicates that exports over the next decade are likely to be appreciably higher than those implied

1/ U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 71, March 1971.

by the USDA/AID study. After discussions with commodity specialists, total export tonnage for 1980 was estimated at 25 million short tons of soybeans and meal -- the latter being 30 percent of the tonnage (see tables 3 and 9). However, the proportionate area distribution is assumed to be about the same as in 1963-68.

Projections for 2000

Since the USDA/AID study was of limited help in projecting from 1980 to 2000, and other studies were found to have a number of weaknesses, it was necessary to make new estimates which rest on a few rather simple but basic assumptions.

Four main assumptions are employed. First, since the demand for soybean meal is closely related to the demand for feed grains, it is assumed that the movement of U.S. soybeans and meal into the world market will be consistent with the projected level of U.S. feed grain exports. Second, it is assumed that although demands in Western Europe will continue to rise, the rate of increase will slacken as these countries begin to approach fairly high levels of per capita meat consumption. Third, it is assumed that the Japanese market will expand very rapidly, and fourth, that the United States will continue to be the dominant world supplier.

Taking up the last point, there is wide agreement that the United States will continue to dominate the world market for soybeans and meal. This is true for a number of reasons. The United States already enjoys a competitive advantage stemming from large economies of scale in the production of soybeans. Potential competing areas are largely labor-intensive with respect to agriculture, and it will likely be a long time before capital-intensive farming on a large scale becomes profitable. Moreover, soybean meal is a widely preferred protein supplement for livestock and poultry feeds; and soybeans have a high yield of meal relative to oil in a market where the demand for meal is growing much more rapidly than the demand for oil. The rapid growth in crushing capacity in Europe designed especially to handle soybeans is an added factor supporting the last two points.

Table 9. Soybeans and Meal: Exports from U.S. to Foreign Port Zones, Projections to 1980 and 2000

(In millions of short tons)

Foreign zones	U.S. zones						
	1 NA	2 SA	3 Gulf	4 Calif.	5 N. Pac.	6 Lakes	Total
1980							
1. Canada						3.3	1.0 a/
2. Atlantic-Carib.			.3				.3
5. Northwest Europe	1.2	.4	7.3			1.5	12.7
6. Med.-Southwest Europe	.2		3.9				4.1
7. Other Mediterranean			1.0				1.0
8. East Europe			.5				.5
12. Southeast Asia	.1		.9				1.0
15. Japan			4.0			.4	4.4
Total	1.5	.4	17.9	--	--	5.2	25.0
2000							
1. Canada						3.8	1.3 a/
2. Atlantic-Carib.			.5				.5
5. Northwest Europe	1.4	.5	9.4			2.2	16.0
6. Med.-Southwest Europe	.3		6.7				7.0
7. Other Mediterranean			1.3				1.3
8. East Europe			.5				.5
12. Southeast Asia	.1		1.5				1.6
15. Japan			10.8			1.0	11.8
Total	1.8	.5	30.7	--	--	7.0	40.0

a/ Estimated transshipments from Canada to Northwest Europe added to total for Foreign Port Zone No. 5.

Returning to the relationship of oilseed meal to grains, an increase in U.S. exports of soybeans and meal between 1980 and 2000 exactly equal to the 66 percent rise in feed grain exports projected for that period would come to about 41.5 million tons. Discussions with commodity analysts tended to center on a range of 900 million to 1 billion bushels of soybeans, with meal exports additional. The higher figure was adopted. Taken in conjunction with the judgment that increased foreign crushing capacity will drop exports of meal to about 25 percent of the total tonnage of soybeans and meal, the resulting export projection becomes 40 million tons -- an increase of about 60 percent above 1980. That figure was adopted (tables 3 and 9).

U.S. and Foreign Interzonal Movements

The basis for the distribution of U.S. exports of feed grains, food grains and soybeans and meal by U.S. and foreign port zones was the zone-to-zone movements in 1968 and 1969 as shown by the U.S. Census. Country projections for 1980 and 2000 were related to appropriate foreign zones and then back to U.S. port zones. For example, projected exports to the EEC, except Italy, were allocated to the Northwest Europe port zone and then back to three U.S. port zones -- Northeast, gulf and Great Lakes. For small countries or areas for which no export projections were made, the percentages of total U.S. exports going to the port zones serving these areas were used for the port-to-port allocations.

The estimates in tables 5 through 8 incorporate, therefore, an assumption that the location of grain and oilseed production will not change drastically between 1970 and 2000. This is not an unusual assumption, especially when all grains are considered, and it is probably valid even for the separate commodities in view of the importance of climatic factors in determining the location of crop production. Irrigation development in the Great Plains may alter this picture, but not to any radical degree. The decline in acreage and annual production of hard spring wheat since 1950 in favor of winter varieties, and the eastward movement of sorghum grain production from the Plains to the western Cornbelt,

are also of little aggregate significance since the bread grains are close substitutes in flour milling and all grains are close substitutes in animal feeds.

Movements from Domestic Producing Areas to U.S. Ports

Assigning grain shipments from U.S. ports to domestic producing areas poses a difficult problem, since national data on interregional grain flows are not available. The USDA estimates of agricultural export shares by regions or states1/ gives some indication of the relative contributions of the different producing areas, but they are heavily weighted by their importance in total national output, which is not necessarily a realistic measure of their contribution to total grain exports.

However, a study by the Economic Research Service of USDA in cooperation with Oklahoma State University2/ provides estimates of least-cost flows of wheat, feed grains and soybeans from 42 producing areas to varying numbers of domestic demand areas and to 13 groups of ports for crops produced in 1966 and marketed during the 1966-67 marketing year. With projected production patterns relatively stable, and assuming no drastic changes in the means of transportation or the rate structure, these past origin-to-port distributions appear to yield a reasonable first approximation of the future pattern.

In order to avoid misleading refinement of this origin-to-port flow, the producing areas and the port

1/ U.S. Department of Agriculture, Economic Research Service, "U.S. Agricultural Shares by Region and State," in Foreign Agricultural Trade, 1968-70.
2/ M.N. Leath and L.V. Blakley, An International Analysis of the United States Grain Marketing Industry, 1966-67, Technical Bulletin 1444, U.S. Department of Agriculture, Economic Research Service, in Cooperation with Oklahoma State University, November 1971.

groupings taken from the study have been consolidated into eight conventional state groupings and the six port zones used in the present study. The results are shown in table 10.

The proportions of total exports of feed grains and soybeans going to the selected ports correspond quite closely with the six port-zone distributions used in the projections. Thus, assigning the projected tonnage by ports back to the producing areas in about the proportions used in this study appears to give a reasonable picture of likely port-to-point-of-origin flows in the target years. The port distributions for wheat are not as symmetrical, because exports to India and Pakistan in 1966-67 were a larger share of the total than is likely in 1980 and 2000. However, the links between producing areas and ports are not likely to change very much, so those based on the ERS study used here can still be utilized.

Table 10. Total Grains: Shipments from Supply Regions to U.S. Port Zones, Projections to 1980 and 2000

(In millions of short tons)

Supply regions	U.S. zones						
	1 NE	2 SE	3 Gulf	4 Calif.	5 N. Pac.	6 Lakes	Total
1980							
Middle Atlantic	1.3	--	--	--	--	--	1.3
East North Central	3.0	.1	14.6	--	--	5.6	23.3
West North Central	1.8	--	12.7	--	--	5.5	20.0
South Atlantic	.7	.4	.8	--	--	--	1.9
East South Central	--	--	4.0	--	--	--	4.0
West South Central	--	--	23.3	1.0	--	--	24.3
Mountain	--	--	--	.4	2.1	--	2.5
Pacific	--	--	--	--	3.7	--	3.7
Total	6.8	.5	55.4	1.4	5.8	11.1	81.0
2000							
Middle Atlantic	1.9	--	--	--	--	8.3	10.2
East North Central	4.5	.1	21.6	--	--	8.2	34.4
West North Central	2.5	--	19.0	--	--		21.5
South Atlantic	1.2	.6	1.2	--	--		3.0
East South Central	--	--	5.9	--	--		5.9
West South Central	--	--	34.4	1.4	--		35.8
Mountain	--	--	--	.6	3.1		3.7
Pacific	--	--	--		5.5		5.5
Total	10.1	.7	82.1	2.0	8.6	16.5	120.0

APPENDIX. REVIEW OF WORLD SUPPLY, DEMAND, AND TRADE STUDIES BY THE U.S. DEPARTMENT OF AGRICULTURE

Introduction

During 1970-71 the U.S. Department of Agriculture released a series of reports containing the results of studies which they had prepared under contract with the Agency for International Development on world demand prospects for various agricultural commodities. While the purpose of the studies was to determine prospects for exports of agricultural commodities from less developed countries, the focus of the data and analyses were on world production, consumption, and trade in these agricultural commodities.

The studies dealing with commodities of concern to us are the following:

1. World Demand Prospects for Agricultural Exports of Less Developed Countries in 1980, Foreign Agricultural Economic Report No. 60, June 1970.

2. World Demand Prospects for Wheat in 1980, Foreign Agricultural Economic Report No. 62, July 1970.

3. Growth in World Demand for Feed Grains, Foreign Agricultural Economic Report No. 63, July 1970.

4. World Supply and Demand Prospects for Oilseeds and Oilseed Products in 1980, Foreign Agricultural Economic Report No. 71, March 1971.

5. World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, December 1971.

In addition, Foreign Agricultural Economic Report No. 53 of June 1969 entitled Japan's Food Demand and 1985 Grain Import Prospects was an in-depth study of the Japanese market for grain imports.

Food and Feed Grains

The most recent of the above reports (FAER No. 75) was found to be the most useful and reliable source of projections for 1980 of U.S. exports of food grains and feed grains by country of destination. It incorporated the results of the basic research and findings of FAER No. 62 and No. 63, but was in itself an independent study of world demand and supply prospects for grains by major country and region, including detailed estimates of exports and imports by countries and regions of origin and destination for 1980. Selected tables from FAER No. 63 appear here as appendix tables 1 through 5, and from FAER No. 75, as appendix tables 6 through 15.

Details as to methodology and assumptions are fully presented in FAER No. 75, and will therefore only be summarized here. Three basic projections of production, consumption, and net trade by country and region for wheat, rice, and coarse grains were made, identified as Projection Sets I, II, and III. Projection Set I assumed the continuation of present food and fiber policies in the less developed countries, allowing for moderate gains in productivity consistent with some improvements in available technology. Under Sets II and III, respectively, higher and lower rates of agricultural productivity and economic growth in the less developed countries were assumed to prevail than under Set I. The Set I projections are considered to be the most realistic and are largely the basis of the RRNA projections of U.S. exports of food and feed grains in 1980. Both Sets I and II are consistent with current national goals of the less developed countries and their development plans designed to accelerate economic growth. Set III illustrates how adverse economic conditions or shortfalls in national development objectives of the less developed countries would affect their export earnings potential.

Both population and income in 1980 for each country and region are key variables in the mathematical model constructed for the study. The population projections are substantially the same as those in annex A-1 of the Deepwater Port Study. National income of the developed and Central Plan countries are identical in each of the projection sets, but are variable in the less developed countries because of the impact on national income of the variable assumptions with respect to agricultural output.

The two key variables used to estimate 1980 export earnings or import costs were the quantities and prices at which grains would be shipped. Quantities and prices were projected within a basic supply-demand framework that assumed interdependency within and among regions. For each projection set, production, consumption, trade, and price levels were determined regionally for each commodity. The basic model was designed to be capable of handling mathematically any number of institutional and policy constraints such as special trading arrangements, quotas, export subsidies and taxes, variable levies, food aid programs, storage capacity and policies, price support programs, and quality differentials among the commodities.

For purposes of illustrating the effect of possible changes in the policies of the developed grain exporting countries, separate projections were made as subsets to Projection Set II, identified as Sets II-A and II-B. Projection Set II-A assumed that grain exporting countries would adopt agricultural support and price policies that would be designed to insure the maintenance of their historical market shares in the world export market. This would mean essentially a lowering of export prices to world market levels, which in the basic model are expected to decline in response to increases in world supplies relative to demand for food and feed grains. In Projection Set II-B the major developed importers, who traditionally have encouraged indigenous production by maintaining relatively high internal prices, would permit such prices to become more sensitive to world price levels, and high internal prices would be adjusted to changes in world prices. The effect of these changes in policy would be a

reduction in grain output in the developed importing countries and an increase in consumption and imports.

Appendix tables 6 and 7 show 1980 projections of wheat production, consumption, and trade under each of the five alternative projection sets, compared with actual data in the 1964-66 base period. In Projection Set I, world consumption of wheat is shown to rise by approximately 92 million metric tons, almost all of which is in the Central Plan and less developed countries. Net imports of the LDC's would increase by roughly 10 million tons over the base period, which, however, is almost exactly offset by a decrease in the net imports of the Central Plan countries. Thus the net exports of major exporting countries, including the United States, Canada, Australia, New Zealand, and Argentina, do not change significantly and, in fact, decline slightly in the aggregate from 46.5 million to 44.2 million tons.

It is of interest to note that the range of aggregate net exports of the major exporting nations in all of the projection sets except Set II is quite narrow, i.e., from 39.0 to 44.9 million metric tons. Under Set II, which assumes a more rapid rate of growth of agriculture production in the less developed countries, the aggregate volume of net exports from major exporters would be 30.3 million tons. The range of net exports from the United States for all projection sets is from 14.8 million tons to a high of 22.6 million.

Appendix tables 8 and 9 present similar data and projections for coarse grains. Under Projection Set I, world consumption is shown as increasing in 1980 by approximately 235 million tons over the base period, about half of which would be in the developed countries, with the balance divided approximately evenly between the Central Plan countries and the less developed countries. However, a somewhat different pattern of change in supply-demand relationships occurs in coarse grains as compared with wheat. Imports of the developed importing countries, including Japan, rise by nearly 7 million tons, compared with a decline in wheat. Aggregate exports from the major developed exporters increase by over 14 million tons, and of major less developed

exporters, by over 4 million tons. The less developed importing countries have an increase of 15 million tons in their annual net import requirements. In Projection Set II, U.S. exports are 21 million tons, and in the other projection sets range from 30 million tons for Set I to a high of 36.7 million for Set II-B.

Projection Set II effectively demonstrates the adverse effect on the growth of U.S. wheat and coarse grain exports of a more rapid rate of growth of output in the less developed countries than that assumed in Projection Set I. Set II-A demonstrates the impact of positive policies by the United States and other major exporting countries to maintain traditional market shares.

Appendix tables 10 through 15 show the data from FAER No. 75 on world trade in wheat and wheat flour and in coarse grains for the base period 1963-65, and as projected for 1980 under Projection Sets I and II.

Oilseed and Oilcake

Appendix tables 16 through 21 are from the Department of Agriculture study on oilseed and oilseed products (FAER No. 71). This study projects for 1980, by country and region, production and consumption of oilseeds, oil cake, and vegetable oils. Three projection sets are used which correspond with those employed in the grain study discussed earlier (FAER No. 75). However, methodology and assumptions other than those included in Projection Sets I, II, and III are substantially different from those employed in the grain study. The projection of supply, demand, and net trade for 1980 by country and region are limited to oil cakes and vegetable oils as a group. Thus the detail required by this study on soybeans and soybean meal are not included in the projections. In addition there are no matrix tables such as those in the grain study showing world trade by country of origin and destination.

Because of the interrelationship between oilseed meal or cake and feed grain consumption in the advanced livestock feeding regions, the study employed an analytical model that jointly considered the demand relationships for both of these major mixed feed ingredients. This model was applied to the major consumers, i.e., Western Europe, North America, and Japan. The demand equation for oilseed meal expressed consumption as a function of oilseed meal price, feed grain price, the quantity of other high protein concentrates consumed, and the production of meat. The feed grain demand equation expressed consumption as a function of the prices of oilseed meal and feed grain and the production of meat. The projection of economic aggregates, i.e., population and income, were the same as those employed in the grain study (FAER No. 75).

In the projections, oilseed meal and feed grain prices were held constant at their 1963-65 average, and meat production was estimated as the mean of the OECD meat production projections for 1975 and 1985.1/

In regions other than Europe, North America, and Japan, little or no interrelationship between oilseed meals and feed grain consumption was found. Hence, the model employed did not include feed grain consumption as a variable.

Production of oilseeds and oilseed cakes by country and region was based largely on a linear extrapolation of historical production data.

Production of the five major oilseeds and eight major types of oilmeal or oil cake by country and region during the base period 1963-65 and as projected for 1980 is shown in appendix tables 16 and 17. In

1/ Organisation for Economic Co-operation and Development, Agricultural Projections for 1975 and 1985; Europe, North America, Japan, and Oceania; Production and Consumption of Major Foodstuffs, Paris, 1968.

the base period, soybeans accounted for approximately 38 percent of total oilseed production, but by 1980 this proportion would rise to 41 percent. Of the total projected world increase in soybean production of 26 million tons, 19.4 million tons would be produced in the United States, with most of the balance coming from Communist Asia and the less developed countries. In 1980, 72 percent of world soybean production would be in the United States.

The predominance of soybeans as a source of oil cake and of the United States as a producer of soybean cake is even greater than is the case with respect to oilseeds. In the base period of 1963-65, soybean meal accounted for 47 percent of total U.S. oil cake production, and in 1980 this would rise to 50 percent. The United States would account for approximately 85 percent of world soybean meal production in both the base period and 1980.

Appendix tables 18, 19, and 20 show the supply, demand, and trade balances for all oil cakes by country and region for the base period and as projected for 1980 under Projection Sets I, II, and III. In the three projection sets the volume of exports from the United States in 1980 ranges from 16.2 to 16.9 million tons. On the other hand the imports of the major developed countries, including Japan, range from a low of 20.7 million under Projection Set III to a high of 25.9 million under Projection Set II. The export surplus of the Central Plan countries is 500,000 tons in each projection set. The export surplus of the less developed countries is 6.3 million tons in 1980 under Projection Set I and 27.0 and 22.1 million tons under Projection Sets II and III, respectively.

Japan

As indicated in the Department of Agriculture grain studies, Japan is emerging as the largest single national net importer of food and feed grains. Set I projections of Japan's net imports in 1980 of wheat and coarse grains are 6.5 million and 16.7 million metric

tons, respectively. In both cases, these equal or exceed the total Western Europe net deficit. The coarse grain deficit is approximately the same as the aggregate net import deficit of all less developed importing countries in 1980.

This growth in the import requirements for wheat and feed grains in Japan is primarily a reflection of the impact on the Japanese diet of recent and prospective rapid increases in per capita income, on the one hand, and Japan's limited capabilities for production of wheat and coarse grains. The projections in appendix tables 6 through 9 do not, however, reflect sufficiently the potential impact on these changes in diet and consequent import requirements of possible alternative economic and trading policies of the Japanese Government. This subject is considered in detail in FAER Report No. 53, which analyzed Japanese food consumption, production, and trade patterns under three hypothetical strategies identified as "Western," "Pacific," and "Eastern." The geographical characterizations may be somewhat misleading, since there is not a literal relationship between them and the elements of the individual strategies.

Appendix table 21 summarizes Japanese consumption of domestic and imported grains for food, for livestock, and for manufacturing under each of the three strategies as estimated for 1985. Under the so-called Western strategy, total grain imports would approximate 50 million metric tons, compared with 24.4 and 18.8 million tons under the Pacific and Eastern strategies, respectively.

The primary emphasis under the Western strategy would be on liberalization of the consumption of meat and wheat and of required imports of wheat and feed grains. Consumption of meat products would approximate 90 kilograms per capita by 1985, nearly the present level of per capita consumption in the United States, and in excess of such consumption levels in other parts of the world. Under the Pacific and Eastern strategies, per capita meat consumption would be approximately 40 and 33 kilograms per capita, respectively.

The decline in grain fed to livestock is even greater, because under both the Pacific and Eastern strategies the growth of indigenous livestock production would be more constrained than under the Western strategy. Under the Pacific strategy, there would be great emphasis on encouraging and assisting in the expansion of livestock production for export to Japan in the entire Pacific basin, including Australia, New Zealand, and Taiwan. Under the Pacific and Eastern strategies, there is likewise greater emphasis on assisting in and encouraging the production of food and feed grains for export to Japan. This would have the effect of decreasing the share of U.S. exports in the Japanese market. Efforts of this nature, some of which have already been successful, have been made in Thailand, Indonesia, Cambodia, Burma, and Australia.

Appendix table 1. World: Grain Consumption Pattern Estimated for 1965, by Region -- Basic Projection, Constant Grain-Meat Ratio

Region or country	All grains				Coarse grain				Wheat and rice			
	Food	Feed	Other	Total	Food	Feed	Other	Total	Food	Feed	Other	Total
	1,000 m.t.											
Developed countries	63,432	194,746	50,642	308,820	9,078	182,347	37,258	228,683	54,354	12,399	13,384	80,137
United States	12,394	102,814	17,499	132,707	2,124	101,621	14,736	118,481	10,270	1,193	2,763	14,226
Canada	1,257	11,042	3,336	15,635	110	9,589	2,897	12,596	1,147	1,453	439	3,039
European Community	18,041	43,356	13,762	75,159	1,873	37,390	9,490	48,753	16,168	5,966	4,272	26,406
EFTA*	8,028	23,047	7,175	38,250	1,863	20,440	6,155	28,458	6,165	2,607	1,020	9,792
Other Western Europe	5,963	8,157	2,375	16,495	242	7,972	1,344	9,558	5,721	185	1,031	6,937
Japan	13,793	3,750	4,589	22,132	855	3,234	1,449	5,538	12,938	516	3,140	16,594
South African Republic	2,821	1,126	755	4,702	1,929	1,110	572	3,611	892	16	183	1,091
Oceania	1,135	1,454	1,151	3,740	82	991	615	1,688	1,053	463	536	2,052
Central plan countries	179,009	89,711	55,447	324,167	48,052	82,317	28,593	158,962	130,957	7,394	26,854	165,205
Soviet Union	38,187	32,927	29,465	100,579	9,528	30,882	13,327	53,737	28,659	2,045	16,138	46,842
Eastern Europe	18,299	37,359	11,200	66,858	6,313	32,663	7,816	46,792	11,986	4,696	3,384	20,066
Communist Asia	122,523	19,425	14,782	156,730	32,211	18,772	7,450	58,433	90,312	653	7,332	98,297
Less developed countries	206,768	29,777	43,904	280,449	64,586	28,512	17,480	110,578	142,182	1,265	26,424	169,871
Middle America	9,978	4,094	3,612	17,684	7,548	3,838	2,719	14,105	2,430	256	893	3,579
East South America**	12,148	11,689	3,614	27,451	2,941	11,689	1,896	16,526	9,207	0	1,718	10,925
West South America	3,501	1,025	874	5,400	1,116	1,025	457	2,598	2,385	0	417	2,802
North Africa	10,907	1,703	1,955	14,565	5,272	1,703	1,332	8,307	5,635	0	623	6,258
West Africa	14,383	197	1,858	16,438	12,687	197	1,704	14,588	1,696	0	154	1,850
East Africa	11,239	616	3,198	15,053	9,118	616	2,926	12,660	2,121	0	272	12,393
West Asia	13,041	7,682	5,774	26,497	957	7,682	1,422	10,061	12,084	0	4,352	16,436
South Asia	92,838	1,562	17,775	112,175	20,359	1,091	3,187	24,637	72,479	471	14,588	87,538
East Asia-Pacific Islands	26,453	904	2,278	29,635	4,521	668	1,684	6,873	21,932	236	594	22,762
Southeast Asia	12,280	305	2,966	15,551	67	3	153	223	12,213	302	2,813	15,328
World total	449,209	314,234	149,993	913,436	121,716	293,176	83,331	498,223	327,493	21,058	66,662	415,213
* Of which: U.K.	4,384	12,136	3,870	20,390	783	10,060	3,437	14,280	3,601	2,076	433	6,110
**Of which: Argentina	2,001	3,022	1,876	6,899	130	3,022	1,133	4,285	1,871	0	743	2,614

Note: U.S. figures do not include grain sorghum. "Other" uses of grain include wet-process products.

Source: Tables 64, 66, 67, and 68.

Reproduced from Growth in World Demand for Feed Grains, 1980, Foreign Agricultural Economic Report No. 63, U.S. Department of Agriculture.

Appendix table 2. Main Sequence of the World Grain-Livestock Economy

Income per capita 1/	Human consumption per capita: Meat 2/: Quantity per year	Meat 2/: Income elasticity	Cereal grain 3/: Quantity per year	Cereal grain 3/: Income elasticity	Grain-meat ratio 4/: Kg. grain per kg. meat	Grain-meat ratio 4/: Income elasticity	Feed grain share 5/: Relative portion	Feed grain share 5/: Income elasticity
Dollar equiv.	Kg.	Rate	Kg.	Rate	Rate	Rate	Pct.	Rate
25	0	z	48.8	.84	0	z	0	z
50	0	z	117.8	.32	0	z	0	z
75	5.2	3.41	144.3	.15	.68	3.72	0	z
100	9.8	1.50	156.5	.07	1.31	1.44	1.63	11.62
125	12.9	1.02	164.3	.01	1.70	.89	5.50	2.91
150	15.2	.82	159.4	-.02	1.96	.65	8.25	1.73
200	18.7	.65	154.9	-.06	2.29	.42	12.07	1.03
250	21.4	.58	148.9	-.09	2.49	.30	14.76	.80
300	23.8	.56	142.8	-.11	2.64	.24	16.89	.69
350	25.9	.55	137.3	-.12	2.74	.20	18.69	.63
400	27.9	.56	132.1	-.13	2.82	.17	20.30	.60
450	29.8	.57	127.5	-.14	2.89	.15	21.78	.59
500	31.6	.63	123.3	-.14	3.22	.12	24.17	.55
750	40.3	.63	107.2	-.16	3.43	.08	30.32	.57
1,000	48.6	.68	96.2	-.17	3.56	.06	35.89	.61
2,000	80.9	.79	75.9	-.18	3.96	.04	56.78	.72
3,000	112.8	.85	61.4	-.18	4.29	.03	77.12	.79

1/ Gross domestic product equivalent.
2/ Equation 1.
3/ Equation 5.
4/ Equation 8.
5/ Portion of animal feed in total domestic disappearance of all grain. Equation 13.

Note: z = infinity.

Reproduced from Growth in World Demand for Feed Grains, 1980, Foreign Agricultural Economic Report No. 63, U.S. Department of Agriculture.

Appendix table 3. Critical Ranges in the Development Sequence of the World Grain-Livestock Economy

Human consumption per capita		Grain allocation to livestock	Grain-meat ratio	Income range per capita
Grain	Meat			
Rising fast -- nearly proportionally to income	None	None	None	Under $60
Rising	Under 10 kg. -- rising more than proportionally to income	Under 1 percent of domestic disappearance	Very low -- below 1.0	$50-100
About level	10 to 20 kg. -- rising proportionally to income	1-12 percent of domestic disappearance	Low -- but doubles to about 2.0	$100-200
Falling	Moderate to high -- rising at 60-80 percent of income rise	Rising from 12-75 percent of domestic disappearance -- about proportionally to rise in meat consumption per capita	Moderate to high -- doubles again to over 4.0	$200-3000
Critical value A	Minimum income elasticity of meat consumption -- .55			($350)
Critical value B		Minimum income elasticity of feed grain share -- .55		($500)

Source: Table 54 and text.

Reproduced from Growth in World Demand for Feed Grains, 1980, Foreign Agricultural Economic Report No. 63, U.S. Department of Agriculture.

Appendix table 4. World: Meat Consumption, Per Capita and Total, by Region, 1962, Estimated 1965, and Projected 1970, 1975, and 1980 -- Basic Projections

Region or country	Per capita					Total				
	1962	1965	1970	1975	1980	1962	1965	1970	1975	1980
	Kg.					1,000 m.t.				
Developed countries	59.3	64.2	69.1	74.0	78.9	37,758	41,847	46,952	52,717	59,298
United States	89.5	95.0	100.0	105.0	110.0	16,703	18,484	20,772	23,434	26,519
Canada	76.6	82.0	87.4	92.8	98.2	1,425	1,607	1,875	2,188	2,555
European Community	58.3	62.4	66.5	70.6	74.7	10,228	11,331	12,475	13,639	14,819
EFTA*	60.8	64.8	68.8	72.8	76.8	5,539	6,042	6,634	7,258	7,913
Other Western Europe	22.1	24.6	27.1	29.6	32.1	1,060	1,206	1,382	1,567	1,770
Japan	6.4	7.5	9.6	12.7	16.9	608	735	978	1,354	1,885
South African Republic	44.5	50.5	56.5	62.5	68.5	741	902	1,161	1,456	1,827
Oceania	110.0	110.0	110.0	110.0	110.0	1,451	1,540	1,675	1,821	2,010
Central plan countries	21.9	24.5	27.1	29.7	32.3	23,648	27,706	32,991	39,168	45,656
Soviet Union	37.5	42.5	47.5	52.5	57.5	8,305	9,800	11,650	13,931	15,946
Eastern Europe	40.8	45.9	51.0	56.1	61.2	4,830	5,574	6,486	7,466	8,492
Communist Asia	14.1	15.5	16.9	18.3	19.7	10,513	12,332	14,855	17,771	21,218
Less developed countries	10.6	11.6	12.6	13.6	14.6	15,062	18,028	21,420	26,752	33,170
Middle America	17.8	19.5	21.2	22.9	24.6	1,297	1,561	1,980	2,503	3,161
East South America**	40.5	42.8	45.1	47.4	49.7	4,424	5,068	4,994	6,048	7,283
West South America	32.9	35.3	37.7	40.1	42.5	1,439	1,682	2,057	2,515	3,071
North Africa	12.0	13.6	15.2	16.8	18.4	831	1,015	1,307	1,673	2,121
West Africa	9.3	10.7	12.1	13.5	14.9	1,142	1,418	1,809	2,295	2,897
East Africa	17.6	20.0	22.4	24.8	27.2	1,397	1,698	2,120	2,676	3,295
West Asia	17.8	20.3	22.8	25.3	27.8	1,445	1,784	2,271	2,889	3,652
South Asia	2.2	2.4	2.6	2.8	3.0	1,306	1,531	1,878	2,283	2,741
East Asia-Pacific Islands	7.2	8.7	10.2	11.7	13.2	1,323	1,728	2,309	3,046	3,946
Southeast Asia	6.1	6.7	7.3	7.9	8.5	458	543	695	824	1,003
World total	24.4	27.0	29.6	32.22	34.8	76,468	87,581	101,363	118,637	138,124
* Of which: U.K.	70.3	74.0	77.7	81.4	85.1	3,758	4,040	4,391	4,775	3,065
** Of which: Argentina	99.6	102.0	104.0	106.0	108.0	2,126	2,280	2,522	2,783	5,165

Note: Assumptions--Population and real income develop as in tables 56 to 59; income elasticities of demand for meat are based on those of table 47; projection equations for per capita meat consumption are linear in the variables: U.S. figure is held to the levels of Oceania and Argentina, and Japan figure is projected with constant income elasticity.

Source: Tables 46, 47, 56, 57, and 59.

Reproduced from Growth in World Demand for Feed Grains, 1980, Foreign Agricultural Economic Report No. 63, U.S. Department of Agriculture.

Appendix table 5. Feed Grain Imports, by Major Importers, 1951-55

Year	Total 1/	Developed nations: Total 1/	EEC	United Kingdom	Other Western Europe 2/	Japan	Eastern Europe	Less developed nations: Total 1/	Latin America	West Asia	South Asia
	1,000 m.t.										
1951 ...	13,556	11,522	4,560	2,455	2,130	1,023	299	1,735	211	130	1,004
1952 ...	15,015	12,688	5,166	2,797	2,010	1,011	833	1,494	95	124	656
1953 ...	15,559	12,956	4,635	3,062	1,629	895	1,087	1,516	529	168	193
1954 ...	15,927	13,292	6,147	2,473	2,274	976	2,000	619	238	131	43
1955 ...	15,249	12,763	5,402	2,889	2,655	1,019	1,458	758	165	331	2
1956 ...	19,479	15,991	8,088	2,827	2,654	1,307	2,278	1,158	316	193	5
1957 ...	18,995	14,330	6,948	2,800	1,988	1,371	2,479	2,127	1,077	363	44
1958 ...	21,478	17,164	7,770	4,371	2,651	1,384	1,503	2,312	1,088	405	141
1959 ...	22,475	19,310	8,822	4,760	3,524	1,430	1,778	1,377	281	500	137
1960 ...	23,611	19,982	9,901	4,162	3,300	1,402	1,944	1,689	376	578	226
1961 ...	25,677	20,276	9,376	4,565	3,017	2,100	1,360	2,560	408	558	158
1962 ...	32,953	26,547	13,434	5,728	3,589	2,732	2,882	2,522	585	637	105
1963 ...	31,431	25,533	13,082	4,212	3,930	3,589	2,980	2,880	994	761	77
1964 ...	34,162	27,899	13,277	4,127	4,921	4,756	2,930	2,785	932	551	125
1965 ...	38,303	32,016	16,548	4,112	5,574	5,626	3,429	2,679	634	677	227

1/ In some years, includes data for regions not shown separately.
2/ Other Western Europe. Includes all European nations except the United Kingdom and the members of the Common Market.

Source: U.S. Dept. Agr., For. Agr. Econ. Rpt. 45, Vol. II.

Reproduced from Growth in World Demand for Feed Grains, 1980, Foreign Agricultural Economic Report No. 63, U.S. Department of Agriculture.

Appendix table 6. Wheat: Production, Consumption, and Trade, 1964-66 Average, and Projections to 1980 Under Projection Sets I and II 1/

Region	1964-66 Produc-tion	1964-66 Consump-tion	1964-66 Net trade 2/	1980--proj. set I Produc-tion	1980--proj. set I Consump-tion	1980--proj. set I Net trade 2/	1980--proj. set II Produc-tion	1980--proj. set II Consump-tion	1980--proj. set II Net trade 2/
	Million metric tons								
Developed:									
Importers--									
EC	28.8	27.7	1.3	36.0	32.1	3.9	35.9	33.4	2.4
United Kingdom	3.8	8.2	-4.3	4.5	8.9	-4.5	4.4	9.0	-4.6
Other W. Europe	10.2	11.5	-1.3	11.2	10.7	.5	11.2	10.6	.6
Japan	1.2	4.8	-3.6	.8	7.3	-6.5	.8	7.3	-6.5
South Africa, Rep. of	.8	1.1	-.4	1.3	1.8	-.5	1.3	1.8	-.5
Subtotal 3/	44.8	53.2	-8.4	53.7	60.8	-7.1	53.6	62.1	-8.5
Major exporters--									
United States	35.5	18.6	21.2	43.2	22.5	19.3	42.8	24.9	14.8
Canada	18.8	4.2	13.8	18.6	4.3	11.9	17.6	4.7	8.7
Australia and New Zealand	10.2	2.7	6.3	11.1	2.8	7.8	10.4	2.8	6.8
Subtotal 3/	64.5	25.5	41.4	72.9	29.6	39.0	70.8	32.5	30.3
Total, developed 3/	109.3	78.8	33.0	126.6	90.4	31.9	124.5	94.6	21.8
Central plan:									
Eastern Europe	20.8	26.6	-5.7	30.7	32.5	-1.8	30.7	32.5	-1.8
USSR	63.1	65.5	-2.4	84.3	79.7	4.6	84.3	79.7	4.6
Communist Asia	22.9	28.6	-5.7	36.0	42.1	-6.1	36.0	42.1	-6.1
Total, central plan 3/	106.8	120.7	-13.8	151.0	154.3	-3.4	150.9	154.3	-3.4
Less developed:									
Importers--									
Cent. Am. & Mexico	1.9	2.9	-1.0	3.2	5.5	-2.3	4.0	6.1	-2.1
East South America	.8	3.8	-3.0	1.2	6.1	-4.9	1.3	6.3	-5.0
West South America	1.6	2.8	-1.2	1.9	5.3	-3.4	2.1	5.6	-3.5
East Africa	.5	.8	-.3	.8	1.5	-.7	.9	1.6	-.7
West Africa	4/	.7	-.6	4/	1.5	-1.5	4/	1.7	-1.6
North Africa	4.1	7.7	-3.6	5.3	14.3	-8.9	5.7	15.3	-9.6
West Asia	12.5	14.4	-1.9	17.9	22.9	-5.0	20.0	24.4	-4.3
South Asia	17.3	26.7	-9.3	43.6	46.0	-2.4	59.9	52.8	7.1
Southeast Asia	4/	.3	-.2	.1	.5	-.4	.1	.6	-.4
East Asia & Pacific Is.	.3	2.4	-2.1	.5	4.6	-4.2	.5	4.9	-4.4
Subtotal 3/	39.1	62.4	-23.3	74.4	108.2	-33.8	94.6	119.2	-24.6
Major exporters--									
Argentina	7.9	3.9	5.1	9.9	4.7	5.2	10.6	4.4	6.2
Total, less developed 3/	47.0	66.3	-18.2	84.3	112.9	-28.6	105.2	123.6	-18.4
World total 3/	263.1	265.7	.9	361.8	357.6	4/	380.6	372.6	4/

1/ Set I assumes a continuation of present food and fiber policies, allowing for moderate gains in productivity in the less developed countries. Set II assumes that agricultural productivity and economic growth in the less developed countries would be higher than projected in set I.
2/ Some regions do not balance because of stocks.
3/ May not add because of rounding.
4/ Less than .05 million.

Reproduced from World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 7. Wheat: Production, Consumption, and Trade, Projections to 1980 Under Projection Sets II-A, II-B, and III 1/

Region	1980--proj. set II-A			1980--proj. set II-B			1980--proj. set III		
	Production	Consumption	Net trade 2/	Production	Consumption	Net trade 2/	Production	Consumption	Net trade 2/
	Million metric tons								
Developed:									
Importers--									
EC	34.9	36.6	-1.7	33.0	36.6	-3.7	36.0	31.1	4.9
United Kingdom	4.4	9.5	-5.2	4.2	9.2	-5.1	4.5	8.9	-4.4
Other W. Europe	11.3	11.2	.1	11.0	11.3	-.4	11.2	10.7	.5
Japan	.8	7.7	-6.9	.8	8.1	-7.3	.8	7.3	-6.5
South Africa, Rep. of	1.0	1.9	-.9	1.3	1.8	-.5	1.3	1.8	-.5
Subtotal 3/	52.4	66.9	-14.5	50.1	67.1	-17.0	53.7	59.8	-6.0
Major exporters--									
United States	56.1	30.3	21.8	51.4	26.9	21.5	43.5	20.8	22.6
Canada	27.4	9.4	13.6	24.3	7.4	13.4	19.3	4.0	14.0
Australia and New Zealand	14.0	3.0	8.3	13.1	2.9	8.2	11.4	2.8	8.4
Subtotal 3/	97.4	42.6	43.7	88.8	37.2	43.1	74.2	27.6	44.9
Total, developed 3/	149.8	109.5	29.1	138.9	104.3	26.1	128.0	87.3	38.9
Central plan:									
Eastern Europe	30.6	32.9	-2.4	30.6	32.8	-2.2	30.7	32.5	-1.8
USSR	83.6	80.3	3.2	83.8	80.1	3.7	84.3	79.8	4.6
Communist Asia	35.7	42.3	-6.6	35.8	42.2	-6.4	36.0	42.1	-6.1
Total, central plan	149.9	155.6	-5.7	150.3	155.1	-4.8	151.0	154.3	-3.3
Less developed:									
Importers--									
Cent. Am. & Mexico	3.9	6.4	-2.6	3.9	6.3	-2.4	2.7	5.1	-2.4
East South America	1.3	6.5	-5.2	1.3	6.4	-5.1	1.0	6.0	-4.9
West South America	2.0	5.8	-3.8	2.1	5.8	-3.7	1.8	5.1	-3.3
East Africa	.9	1.7	-.8	.9	1.7	-.8	.7	1.4	-.7
West Africa	4/	1.7	-1.7	4/	1.7	-1.7	4/	1.4	-1.4
North Africa	5.5	15.4	-9.9	5.6	15.4	-9.8	5.1	13.7	-8.6
West Asia	19.9	24.6	-4.7	20.0	24.5	-4.5	16.4	22.0	-5.7
South Asia	59.9	54.0	5.9	59.9	53.4	6.6	35.4	43.5	-8.1
Southeast Asia	.1	.6	-.5	.1	.6	-.4	.1	.5	-.4
East Asia & Pacific Is.	.5	5.2	-4.7	.5	5.1	-4.6	.4	4.4	-4.0
Subtotal 3/	94.1	122.0	-27.9	94.4	120.8	-26.4	63.7	103.3	-39.7
Major exporters--									
Argentina	9.2	4.7	4.5	9.7	4.6	5.1	8.9	4.8	4.1
Total, less developed 3/	103.3	126.8	-23.4	104.2	125.4	-21.2	72.6	108.2	-35.6
World total 3/	403.0	391.8		393.4	384.8		351.6	349.8	

1/ Set II-A assumes that major developed exporters would maintain their traditional share of the world market. Set II-B assumes that the major developed importers would become more sensitive to world grain prices and adjust their high internal prices to changes in world prices. Set III assumes that agricultural productivity and economic growth in the less developed countries would be lower than projected in Set I.
2/ Some regions do not balance because of stocks.
3/ May not add because of rounding.
4/ Less than .05 million.

Reproduced from World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 8. Coarse Grains: Production, Consumption, and Trade, 1964-66 Average, and Projections to 1980 Under Projection Sets I and II 1/

Region	1964-66			1980--proj. set I			1980--proj. set II		
	Production	Consumption	Net trade 2/	Production	Consumption	Net trade 2/	Production	Consumption	Net trade 2/
	Million metric tons								
Developed:									
Importers--									
EC	30.9	43.0	-11.9	50.7	60.8	-10.0	50.6	59.9	-9.3
United Kingdom	9.5	13.0	-3.5	14.5	16.3	-1.7	14.4	17.3	-2.9
Other W. Europe	19.4	24.9	-5.6	28.1	33.2	-5.1	27.9	34.1	-6.2
Japan	1.4	7.5	-6.0	1.0	17.7	-16.7	1.0	18.2	-17.2
Subtotal 3/	61.2	88.2	-26.9	94.4	128.0	-33.6	94.0	129.5	-35.6
Major exporters--									
United States	136.6	124.5	21.8	210.5	179.8	30.0	206.9	184.2	21.0
Canada	14.1	13.5	.7	18.3	17.3	1.1	18.1	17.7	.4
Australia and New Zealand	3.1	2.4	.7	6.3	3.5	2.8	6.2	3.6	2.7
South Africa, Rep. of	5.1	4.6	.5	11.0	7.1	3.9	10.8	7.3	3.4
Subtotal 3/	159.0	145.0	23.6	246.2	207.7	37.8	242.0	212.8	27.5
Total, developed 3/	220.1	223.4	-3.3	340.6	335.7	4.2	335.9	342.4	-8.1
Central plan:									
Eastern Europe	44.0	44.4	-.4	55.5	54.5	1.1	55.5	54.4	1.0
USSR	51.6	51.3	.3	78.0	77.2	.7	77.9	77.3	.6
Communist Asia	46.9	46.8	.1	66.5	66.8	-.3	66.4	66.8	-.4
Total, central plan 3/	142.5	142.5		199.9	198.4	1.5	199.8	198.6	1.2
Less developed:									
Importers--									
Cent. Am. & Mexico	11.1	10.5	.7	18.0	20.2	-2.2	22.1	22.7	-.7
West South America	2.8	2.9	-.1	3.2	4.4	-1.2	3.3	4.5	-1.2
West Africa	11.1	11.1	.1	14.0	16.8	-2.8	15.4	17.6	-2.2
North Africa	6.4	6.5	.1	11.1	12.1	-1.0	13.1	13.5	-.4
West Asia	8.3	8.8	-.5	11.0	13.8	-2.8	12.1	14.6	-2.6
South Asia	25.8	27.2	-1.3	37.0	39.8	-2.8	41.4	43.8	-2.4
East Asia & Pacific Is.	6.4	6.8	-.3	12.0	15.7	-3.7	15.3	16.7	-1.3
Subtotal 3/	72.0	73.6	-1.6	106.3	122.8	-16.6	122.7	133.5	-10.7
Major exporters--									
Argentina	9.0	3.9	5.2	13.4	6.4	7.0	15.1	6.7	8.4
East South America	11.6	11.3	.2	20.1	19.1	1.0	23.8	20.7	3.0
East Africa	12.1	12.2	-.1	20.0	18.8	1.2	23.8	20.6	3.3
Southeast Asia	1.4	.2	1.3	3.5	1.9	1.6	4.9	2.0	2.9
Subtotal 3/	34.1	27.6	6.6	57.0	46.2	10.8	67.6	49.9	17.6
Total, less developed 3/	106.1	101.4	5.2	163.3	169.0	-5.8	190.3	183.4	6.9
World total 3/	468.7	477.0	1.7	703.8	703.1		726.0	724.3	

1/ Set I assumes a continuation of present food and fiber policies, allowing for moderate gains in productivity in the less developed countries. Set II assumes that agricultural productivity and economic growth in the less developed countries would be higher than projected in Set I.
2/ Some regions do not balance because of stocks.
3/ May not add because of rounding.

Reproduced from World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 9. Coarse Grains: Production, Consumption, and Trade, Projections to 1980 Under Projection Sets II-A, II-B, and III 1/

Region	1980--proj. set II-A			1980--proj. set II-B			1980--proj. set III		
	Production	Consumption	Net trade 2/	Production	Consumption	Net trade 2/	Production	Consumption	Net trade 2/
	Million metric tons								
Developed:									
Importers--									
EC	50.1	59.8	-9.7	50.3	62.8	-12.6	50.8	60.7	-9.9
United Kingdom	14.2	19.6	-5.4	13.3	18.3	-5.1	14.6	16.2	-1.6
Other W. Europe	27.7	35.3	-7.6	26.9	36.9	-10.0	28.2	32.7	-4.5
Japan	1.0	20.4	-19.4	1.0	21.5	-20.5	1.0	17.4	-16.4
Subtotal 3/	93.0	135.1	-42.0	91.4	139.6	-48.1	94.6	127.1	-32.4
Major exporters--									
United States	232.2	194.7	33.6	299.8	190.4	36.7	212.9	177.0	35.8
Canada	17.8	15.1	2.5	17.9	16.1	1.8	18.5	17.0	1.6
Australia and New Zealand	5.9	3.6	2.3	6.1	3.6	2.5	6.4	3.5	2.9
South Africa, Rep. of	10.3	7.9	2.5	10.5	7.6	2.9	11.2	6.9	4.2
Subtotal 3/	266.3	221.3	41.0	264.3	217.7	43.8	249.1	204.4	44.6
Total, developed 3/	359.3	356.4	-1.0	355.8	357.3	-4.3	343.7	331.5	12.1
Central plan:									
Eastern Europe	55.1	54.9	.2	55.3	54.7	.5	55.5	54.3	1.2
USSR	77.6	77.4	.2	77.7	77.3	.4	78.0	77.2	.8
Communist Asia	66.4	66.9	-.5	66.4	66.8	-.4	66.5	66.8	-.3
Total, central plan 3/	199.0	199.2	-.1	199.4	198.9	.5	200.0	198.3	1.7
Less developed:									
Importers--									
Cent. Am. & Mexico	21.8	23.0	-1.2	21.9	22.9	-1.0	15.7	18.8	-3.1
West South America	3.3	4.6	-1.3	3.3	4.6	-1.2	3.0	4.3	-1.3
West Africa	15.3	17.7	-2.4	15.3	17.6	-2.3	13.1	16.3	-3.3
North Africa	13.1	13.7	-.6	13.1	13.6	-.5	9.6	11.3	-1.6
West Asia	12.0	15.0	-3.0	12.0	14.8	-2.8	10.3	13.3	-3.0
South Asia	41.3	43.9	-2.6	41.4	43.9	-2.5	33.7	36.9	-3.2
East Asia & Pacific Is.	15.1	17.0	-1.8	15.2	16.8	-1.6	9.9	15.1	-5.2
Subtotal 3/	121.9	134.9	-12.9	122.3	134.2	-11.9	95.4	116.1	-20.8
Major exporters--									
Argentina	14.9	7.1	7.8	15.0	6.9	8.2	12.2	6.2	6.0
East South America	22.8	22.0	.8	23.3	21.4	1.8	17.8	17.8	4/
East Africa	23.5	20.8	2.7	23.6	20.7	3.0	17.6	17.6	4/
Southeast Asia	4.7	2.0	2.7	4.8	2.0	2.8	2.8	1.9	.9
Subtotal 3/	65.9	51.9	14.0	66.8	51.0	15.8	50.4	43.5	6.9
Total, less developed 3/	187.9	186.8	1.1	189.1	185.2	3.9	145.7	159.6	-13.9
World total 3/	746.2	742.4		744.2	741.4		689.4	689.4	

1/ Set II-A assumes that major developed exporters would maintain their traditional share of the world market. Set II-B assumes that the major developed importers would become more sensitive to world grain prices and adjust their high internal prices to changes in world prices. Set III assumes that agricultural productivity and economic growth in the less developed countries would be lower than projected in Set I.
2/ Some regions do not balance because of stocks.
3/ May not add because of rounding.
4/ Less than .05 million.

Reproduced from World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 10. World Trade in Wheat and Wheat Flour, 1963-65 Average

Exporting Regions	Developed: United States	Developed: Canada	Developed: Japan	Developed: EC	Developed: United Kingdom	Developed: Other West Europe	Developed: Aust. N.Z. S. Afr.	Developed: Sub-total	Central Plan: East Europe	Central Plan: USSR	Central Plan: Communist Asia	Central Plan: Sub-total	Less developed: Argentina	Less developed: Other Latin Am.	Less developed: North Africa	Less developed: West Africa	Less developed: East Africa	Less developed: West Asia	Less developed: South Asia	Less developed: South-east Asia	Less developed: Other East Asia	Less developed: F. East & Oceania	Less developed: Sub-total	World total exports
									1,000 metric tons															
Developed:																								
United States	—	—	1,753	1,111	311	570	47	3,792	1,608	595	—	2,203	—	2,547	2,155	199	38	1,241	6,896	143	1,185	114	14,518	20,513
Canada	77	—	1,322	1,361	2,282	524	108	5,664	1,293	3,437	1,537	6,267	—	795	4	77	7	46	168	16	217	59	1,399	13,221
Japan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	30	41	76	76
EC	—	—	9	613	687	401	—	1,710	1,115	521	451	2,090	—	140	679	194	71	121	93	6	13	38	1,355	5,155
United Kingdom	—	—	—	—	—	67	—	67	—	—	—	—	—	—	26	—	4	16	1	—	—	—	47	585
Other West Europe	—	—	—	137	68	—	—	205	266	—	—	266	—	—	—	—	—	—	—	—	—	—	—	—
Australia, N. Zeal., Un. S. Afr.	—	—	429	52	620	191	175	1,467	17	902	2,503	3,422	—	3	14	—	100	373	451	32	99	270	1,342	6,231
Subtotal	77	—	3,513	3,274	3,968	1,743	330	12,905	4,202	5,455	4,202	14,148	—	3,486	2,878	470	220	1,797	7,609	202	1,544	522	18,725	45,781
Central Plan:																								
Eastern Europe	—	—	—	2	1	4	—	7	39	9	—	48	—	—	—	—	—	—	15	—	—	—	15	70
USSR	—	—	14	68	100	153	—	355	1,823	—	—	1,823	—	452	63	—	—	2	3	—	44	—	564	2,742
Communist Asia	—	—	—	—	—	—	—	—	—	52	—	52	—	—	—	—	—	—	1	—	1	—	2	54
Subtotal	—	—	14	90	101	157	—	362	1,862	61	—	1,923	—	452	63	—	—	2	19	—	45	—	581	2,866
Less Developed:																								
Argentina	—	—	1	772	298	144	—	1,215	176	290	837	1,303	—	1,396	20	—	12	17	—	—	4	—	1,449	3,967
Other Latin America	—	—	—	7	—	—	—	7	17	—	—	17	—	40	—	3	—	5	—	—	—	—	48	72
North Africa	—	—	—	57	1	5	—	63	4	—	—	4	—	—	10	—	—	—	—	—	—	—	10	77
West Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	2	—	—	—	—	5	5
East Africa	—	—	—	4	—	—	—	4	—	—	—	—	—	—	—	—	4	—	—	—	—	—	4	8
West Asia	—	—	—	24	—	—	—	24	—	—	—	—	—	—	4	—	—	45	—	1	—	—	50	74
South Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	3	3
South E. Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	1
Other E. Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	9	19	23	54	54
Far East & Oceania	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	20	21	21
Subtotal	—	—	1	864	299	149	—	1,313	197	290	837	1,324	—	1,436	34	4	19	72	4	10	23	43	1,645	4,282
WORLD TOTAL IMPORTS	77	—	3,528	4,228	4,368	2,049	330	14,580	6,261	5,806	5,328	17,395	—	5,374	2,975	474	239	1,871	7,632	212	1,617	565	20,954	52,929

Source: Computed from tables 66-65 in (89).

Reproduced from <u>World Demand Prospects for Grain in 1980</u>, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 11. World Trade in Wheat, 1980, Projection Set I[1/]

Exporting Regions	Importing Regions: Developed: United States	Canada	Japan	EC	United Kingdom	OWE	South Africa Rep.	Aust. & N.Z.	Sub-total	Central Plan: East Europe	USSR	Communist Asia	Sub-total	Less Developed: Cent. Amer.	East S. Amer.	West S. Amer.	Argentina	North Africa	West Africa	East Africa	West Asia	South Asia	South-east Asia	East Asia & Pac. Is.	Sub-total	World total exports
										1,000 metric tons																
Developed:																										
United States	—	—	3,923	1,000	449	—	—	—	5,372	—	—	—	—	2,283	2,086	—	—	3,370	—	—	4,092	2,114	—	—	13,945	19,317
Canada	—	—	1,961	1,000	3,141	—	—	—	6,102	—	—	3,254	3,254	—	—	2,427	—	—	—	—	—	114	—	—	2,541	11,897
Japan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EC	—	—	—	—	—	—	—	—	—	1,095	—	—	1,095	—	—	—	—	2,135	1,483	712	—	151	304	—	4,785	5,880
United Kingdom	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other W. Europe	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	508	—	—	—	—	—	—	508	508
S. Africa Rep	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Austr. & N.Z.	—	—	654	—	—	—	—	—	654	—	—	2,858	2,858	—	—	—	—	—	—	—	—	—	127	4,179	4,306	7,818
Subtotal	—	—	6,538	2,000	3,590	—	—	—	12,128	1,095	—	6,112	7,207	2,283	2,086	2,427	—	6,013	1,483	712	4,092	2,379	431	4,179	26,085	45,420
Central Plan:																										
Eastern Europe	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
USSR	—	—	—	—	—	—	—	—	—	730	—	—	730	—	—	—	—	2,934	—	—	916	—	—	—	3,850	4,580
Communist Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	730	—	—	730	—	—	—	—	2,934	—	—	916	—	—	—	3,850	4,580
Less Developed:																										
Central America	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E. South America	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
W. South America	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Argentina	—	—	—	—	897	—	473	—	1,370	—	—	—	—	—	2,840	985	—	—	—	—	—	—	—	—	3,825	5,195
North Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
West Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
East Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
West Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
South Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Southeast Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
East Asia & Pac. Is.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	897	—	473	—	1,370	—	—	—	—	—	2,840	985	—	—	—	—	—	—	—	—	3,825	5,195
World total imports	—	—	6,538	2,000	4,487	—	473	—	13,498	1,825	—	6,112	7,937	2,283	4,926	3,412	—	8,947	1,483	712	5,008	2,379	431	4,179	33,760	55,195

1/ Set I assumes a continuation of present food and fiber policies, allowing for moderate gains in productivity in the LDC's.

Reproduced from World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 12. World Trade in Wheat, 1980, Projection Set II 1/

Exporting Regions	Developed: United States	Developed: Canada	Developed: Japan	Developed: EC	Developed: United Kingdom	Developed: Other West Europe	Developed: South Africa: Rep.	Developed: Aust. & N.Z.	Developed: Sub-total	Central Plan: East Europe	Central Plan: USSR	Central Plan: Communist Asia	Central Plan: Sub-total	Less Developed: Cent. Am.	Less Developed: East South Am.	Less Developed: West South Am.	Less Developed: Argentina	Less Developed: North Africa	Less Developed: West Africa	Less Developed: East Africa	Less Developed: West Asia	Less Developed: South Asia	Less Developed: South East Asia	Less Developed: E Asia & Pac. Is.	Less Developed: Sub-total	World trade exports
	1,000 metric tons																									
Developed																										
United States	—	—	2,952	1,000	457	—	—	—	4,409	—	—	—	—	2,101	1,152	—	—	5,115	—	—	—	2,000	—	—	10,366	14,777
Canada	—	—	1,940	1,000	3,201	—	—	—	6,141	—	—	—	—	—	73	2,533	—	—	—	—	—	—	—	—	2,606	8,747
Japan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EC	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
United Kingdom	—	—	—	—	—	—	—	—	—	1,105	—	—	1,105	—	—	—	—	995	1,624	704	—	—	—	—	3,323	4,428
Other West Europe	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
South Africa, Rep.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	572	—	—	—	—	—	—	572	572
Australia & New Zealand	—	—	1,575	—	—	—	—	—	1,575	—	—	5,220	5,220	—	—	—	—	—	—	—	—	—	—	—	—	6,795
Subtotal	—	—	6,467	2,000	3,658	—	—	—	12,125	1,105	—	5,220	6,325	2,101	1,225	2,533	—	6,682	1,624	704	—	2,000	—	—	16,869	35,319
Central Plan:																										
Eastern Europe	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
USSR	—	—	—	—	—	—	—	—	—	737	—	—	737	—	—	—	—	2,930	—	—	917	—	—	—	3,847	4,584
Communist Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	—	—	—	—	737	—	—	737	—	—	—	—	2,930	—	—	917	—	—	—	3,647	4,584
Less Developed:																										
Central America	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
East South America	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
West South America	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Argentina	—	—	—	—	915	—	460	—	1,375	—	—	—	—	—	3,779	1,001	—	—	—	—	—	—	—	—	4,780	6,155
North Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
West Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
East Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
West Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
South Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
South East Asia	—	—	—	—	—	—	—	—	—	—	—	907	907	—	—	—	—	—	—	—	3,402	—	417	4,413	8,232	9,139
East Asia & Pacific Is.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	915	—	460	—	1,375	—	—	907	907	—	3,779	1,001	—	—	—	—	3,402	—	417	4,413	13,012	15,294
WORLD TOTAL IMPORTS	—	—	6,467	2,000	4,573	—	460	—	13,500	1,842	—	6,127	7,969	2,101	5,004	3,534	—	9,612	1,624	704	4,319	2,000	417	4,423	33,728	55,197

1/ Set II assumes that agricultural productivity and economic growth in the LDC's would be higher than projected in set I. Set I assumes a continuation of present food and fiber policies, allowing for moderate gains in productivity in the LDC's.

Reproduced from World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 13. World Trade in Coarse Grains, 1963-65 Average

Exporting Regions	Importing Regions: Developed: United States	Canada	Japan	EC	United Kingdom	Other West Europe	Aust. N.Z. S. Afr.	Sub-total	Central Plan: East Europe	USSR	Communist Asia	Sub-total	Less developed: Argentina	Other Latin Am.	North Africa	West Africa	East Africa	West Asia	South Asia	South-east Asia	Other East Asia	F. East & Oceania	Sub-total	World total exports
	1,000 metric tons																							
Developed:																								
United States	—	374	2,802	6,904	2,091	2,181	—	14,350	303	—	—	303	2	388	278	79	33	384	139	16	183	—	1,502	16,155
Canada	151	—	125	298	485	98	—	1,157	28	—	171	199	—	20	—	1	1	—	—	—	12	—	34	1,390
Japan	—	—	—	—	—	—	—	0	—	—	—	0	—	—	—	—	—	—	—	—	—	—	0	0
EC	12	—	4	1,783	476	1,188	—	3,463	285	—	52	336	—	7	7	10	—	7	—	—	—	—	31	3,830
United Kingdom	—	—	—	111	0	35	—	146	41	—	—	41	—	0	0	—	—	0	—	—	—	—	0	187
Other West Europe	1	—	—	271	30	135	—	437	67	—	—	67	—	10	1	—	—	25	—	—	—	—	36	540
Australia, N. Zeal., Un. S. Afr.	9	—	582	645	645	65	2	1,948	7	—	14	21	—	36	—	3	65	14	1	—	10	2	134	2,103
Subtotal	173	374	3,511	10,012	3,727	3,702	2	21,501	731	—	236	967	2	461	286	93	102	430	140	16	205	2	1,737	24,205
Central Plan:																								
Eastern Europe	—	—	55	513	153	291	—	1,012	362	—	—	362	—	4	—	—	—	27	—	—	—	—	31	1,406
USSR	—	—	42	150	—	140	—	332	1,522	—	—	1,522	—	190	—	—	—	—	—	—	—	—	190	2,044
Communist Asia	—	—	144	—	—	—	—	144	—	—	—	0	—	6	—	—	—	—	—	—	—	—	6	150
Subtotal	—	—	241	663	153	431	—	1,488	1,884	—	—	1,884	—	200	—	—	—	27	—	—	—	—	227	3,599
Less Developed:																								
Argentina	13	—	148	2,963	162	325	—	3,611	38	—	126	164	—	130	—	—	—	13	—	—	3	—	146	3,921
Other Latin America	3	—	110	385	53	21	—	572	305	—	—	305	—	59	—	8	1	3	—	—	9	—	80	957
North Africa	—	—	—	99	10	162	—	271	15	—	—	15	0	0	15	1	—	14	—	—	—	—	30	316
West Africa	—	—	—	—	5	87	—	92	—	—	—	0	0	0	—	5	—	—	—	—	—	—	5	97
East Africa	—	—	42	30	34	0	—	106	—	—	—	0	—	—	—	3	33	—	—	—	—	—	36	142
West Asia	—	—	1	132	5	80	—	218	58	—	—	58	0	0	7	—	—	163	—	—	—	—	170	446
South Asia	—	—	—	2	—	—	—	2	77	—	—	77	—	—	—	—	—	—	—	—	—	—	0	79
South East Asia	—	—	599	17	—	—	—	616	5	—	3	8	—	—	—	—	23	10	3	—	138	166	340	964
Other East Asia	—	—	5	—	—	—	—	5	—	—	—	0	—	—	—	—	—	—	—	—	5	—	5	10
Far East & Oceania	—	—	1	—	—	—	—	1	—	—	—	0	—	—	—	—	—	—	—	—	—	1	1	2
Subtotal	16	0	906	3,628	269	675	0	5,494	498	—	129	627	0	627	22	17	57	203	3	—	155	167	813	6,934
WORLD TOTAL IMPORTS	189	374	4,658	14,303	4,149	4,808	2	28,483	3,113	—	365	3,478	—	850	308	110	159	660	143	16	360	169	2,777	34,738

Source: Computed from tables 51-53 in (89).

Reproduced from World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 14. World Trade in Coarse Grains, 1980, Projection Set I[1/]

Exporting Regions	Importing Regions: Developed: United States	Canada	Japan	EC	United Kingdom	OWE	South Africa Rep.	Aust. & N.Z.	Subtotal	Central Plan: East Europe	USSR	Communist Asia	Subtotal	Less Developed: Cent. Amer.	East S. Amer.	West S. Amer.	Argentina	North Africa	West Africa	East Africa	West Asia	South Asia	Southeast Asia	East Asia &	Subtotal	World total exports
	1,000 metric tons																									
Developed:																										
United States	—	—	14,620	5,445	861	2,246	—	—	26,372	—	—	—	—	2,208	—	—	—	—	—	—	—	1,400	—	—	3,608	29,580
Canada	—	—	—	—	861	202	—	—	1,063	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1,063
Japan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EC	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
United Kingdom	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other W. Europe	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S. Africa Rep.	—	—	—	—	—	—	—	—	—	—	—	298	298	—	—	—	—	—	—	—	1,581	1,400	—	631	3,612	3,910
Austr. & N.Z.	—	—	1,131	—	—	—	—	—	1,131	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1,697	1,697	2,828
Subtotal	—	—	15,951	8,445	1,722	2,448	—	—	28,566	—	—	—	—	—	—	—	—	—	—	—	1,581	2,800	—	2,328	8,917	37,781
Central Plan:																										
Eastern Europe	—	—	—	—	—	134	—	—	134	—	—	—	—	—	—	—	—	973	—	—	—	—	—	—	973	1,107
USSR	—	—	—	—	—	736	—	—	736	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	736
Communist Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	—	—	—	870	—	—	870	—	—	—	—	—	—	—	—	973	—	—	—	—	—	—	973	1,843
Less Developed:																										
Central America	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E. South America	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1,044	—	—	—	—	—	—	—	—	1,044	1,044
W. South America	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Argentina	—	—	—	1,596	—	1,770	—	—	3,366	—	—	—	—	—	—	179	—	—	2,842	—	—	—	—	610	3,631	6,997
North Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
West Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
East Africa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1,208	—	—	—	1,208	1,208
West Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
South Asia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Southeast Asia	—	—	785	—	—	—	—	—	785	—	—	—	—	—	—	—	—	—	—	—	—	—	—	785	785	1,570
East Asia & Pac. Is.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotal	—	—	785	1,596	—	1,770	—	—	4,151	—	—	—	—	—	—	1,223	—	—	2,842	—	1,208	—	—	1,395	6,668	10,819
World total imports	—	—	15,736	10,041	1,722	5,658	—	—	33,587	—	—	298	298	2,206	—	1,223	—	973	2,842	—	2,789	2,800	—	3,723	16,558	50,443

1/ Set I assumes a continuation of present food and fiber policies, allowing for moderate gains in productivity in the LDC's.

Reproduced from World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 15. World Trade in Coarse Grains, 1980, Projection Set II[1/]

Importing Regions — 1,000 metric tons

Exporting Regions	Developed: United States	Developed: Canada	Developed: Japan	Developed: EC	Developed: United Kingdom	Developed: Other West Europe	Developed: South Africa Rep.	Developed: Aust. & N.Z.	Developed: Sub-total	Central plan: East Europe	Central plan: USSR	Central plan: Communist Asia	Central plan: Sub-total
Developed:													
United States	--	--	10,427	6,683	2,057	--	--	--	29,167	--	--	--	--
Canada	--	--	--	--	365	--	--	--	365	--	--	--	--
Japan	--	--	--	--	--	--	--	--	--	--	--	--	--
EC	--	--	--	--	--	--	--	--	--	--	--	--	--
United Kingdom	--	--	--	--	--	--	--	--	--	--	--	--	--
Other West Europe	--	--	--	--	--	--	--	--	--	--	--	--	--
South Africa, Rep.	--	--	2,684	--	--	--	--	--	2,684	--	--	370	376
Australia & New Zealand	--	--	2,675	--	--	--	--	--	2,675	--	--	--	--
Subtotal	--	--	15,786	6,683	2,422	--	--	--	24,891	--	--	376	376
Central Plan:													
Eastern Europe	--	--	--	523	492	--	--	--	1,015	--	--	--	--
USSR	--	--	--	--	--	196	--	--	196	--	--	--	--
Communist Asia	--	--	--	--	--	--	--	--	--	--	--	--	--
Subtotal	--	--	--	523	492	196	--	--	1,211	--	--	--	--
Less Developed:													
Central America	--	--	--	--	--	--	--	--	--	--	--	--	--
East South America	--	--	--	596	--	--	--	--	596	--	--	--	--
West South America	--	--	--	--	--	--	--	--	--	--	--	--	--
Argentina	--	--	--	1,483	--	5,969	--	--	7,452	--	--	--	--
North Africa	--	--	--	--	--	--	--	--	--	--	--	--	--
West Africa	--	--	--	--	--	--	--	--	--	--	--	--	--
East Africa	--	--	--	--	--	--	--	--	--	--	--	--	--
West Asia	--	--	--	--	--	--	--	--	--	--	--	--	--
South Asia	--	--	--	--	--	--	--	--	--	--	--	--	--
South East Asia	--	--	1,444	--	--	--	--	--	1,444	--	--	--	--
East Asia & Pacific Is.	--	--	--	--	--	--	--	--	--	--	--	--	--
Subtotal	--	--	1,444	2,079	--	5,969	--	--	9,492	--	--	--	--
WORLD TOTAL IMPORTS	--	--	17,230	9,285	2,914	6,165	--	--	35,594	--	--	376	376

Exporting Regions	Less Developed: Cent. Am.	Less Developed: East South Am.	Less Developed: West South Am.	Less Developed: Argentina	Less Developed: North Africa	Less Developed: West Africa	Less Developed: East Africa	Less Developed: West Asia	Less Developed: South Asia	Less Developed: South East Asia	Less Developed: E Asia & Pac. Is.	Less Developed: Sub-total	World total exports
Developed:													
United States	653	--	--	--	--	--	--	--	1,210	--	--	1,863	21,030
Canada	--	--	--	--	--	--	--	--	--	--	--	--	365
Japan	--	--	--	--	--	--	--	--	--	--	--	--	--
EC	--	--	--	--	--	--	--	--	--	--	--	--	--
United Kingdom	--	--	--	--	--	--	--	--	--	--	--	--	--
Other West Europe	--	--	--	--	--	--	--	--	--	--	--	--	--
South Africa, Rep.	--	--	--	--	--	--	--	--	382	--	--	382	3,442
Australia & New Zealand	--	--	--	--	--	--	--	--	--	--	--	--	2,675
Subtotal	653	--	--	--	--	--	--	--	1,592	--	--	2,245	27,512
Central Plan:													
Eastern Europe	--	--	--	--	--	--	--	--	--	--	--	--	1,015
USSR	--	--	--	--	378	--	--	--	--	--	--	378	574
Communist Asia	--	--	--	--	--	--	--	--	--	--	--	--	--
Subtotal	--	--	--	--	378	--	--	--	--	--	--	378	1,589
Less Developed:													
Central America	--	--	--	--	--	--	--	--	--	--	--	--	--
East South America	--	--	1,168	--	--	1,267	--	--	--	--	--	2,435	3,031
West South America	--	--	--	--	--	--	--	--	--	--	--	--	--
Argentina	--	--	--	--	--	970	--	--	--	--	--	970	8,422
North Africa	--	--	--	--	--	--	--	--	--	--	--	--	--
West Africa	--	--	--	--	--	--	--	--	--	--	--	--	--
East Africa	--	--	--	--	--	--	--	2,559	717	--	--	3,276	3,276
West Asia	--	--	--	--	--	--	--	--	--	--	--	--	--
South Asia	--	--	--	--	--	--	--	--	--	--	--	--	--
South East Asia	--	--	--	--	--	--	--	--	111	--	1,332	1,443	2,587
East Asia & Pacific Is.	--	--	--	--	--	--	--	--	--	--	--	--	--
Subtotal	--	--	1,168	--	--	2,237	--	2,559	828	--	1,332	8,124	17,616
WORLD TOTAL IMPORTS	653	--	1,168	--	378	2,237	--	2,559	2,420	--	1,332	10,747	46,717

1/ Set II assumes that agricultural productivity and economic growth in the LDC's would be higher than projected in set I. Set I assumes a continuation of present food and fiber policies, allowing for moderate gains in productivity in the LDC's.

Reproduced from World Demand Prospects for Grain in 1980, Foreign Agricultural Economic Report No. 75, U.S. Department of Agriculture.

Appendix table 16. -Production of Oilseeds, by Region, Average 1963-65, and Projections for 1980

Region	Cottonseed 1963-65	Cottonseed 1980	Peanuts 1963-65	Peanuts 1980	Rapeseed 1963-65	Rapeseed 1980	Soybeans 1963-65	Soybeans 1980	Sunflowerseed 1963-65	Sunflowerseed 1980
	-1,000 metric tons									
United States	5,596	6,274	999	1,765	--	--	20,376	39,695	--	--
Canada	--	--	--	--	334	900	182	300	15	30
EC	10	--	10	3	357	1,200	--	--	31	50
O.W.E.	327	384	13	15	239	500	--	--	3	10
South Africa	31	48	216	340	--	--	--	--	83	120
Australia-New Zealand	9	78	21	50	--	--	--	--	--	--
Eastern Europe	30	45	2	--	571	1,400	10	100	1,110	2,400
USSR	3,338	4,863	--	--	5	--	376	900	4,359	8,000
Communist Asia	2,716	4,116	2,164	3,600	633	1,000	7,151	10,000	66	99
Mexico & Central America	1,295	1,416	161	200	6	5	40	450	--	--
South America	1,781	2,962	1,020	1,900	54	100	450	1,500	667	1,800
East and West Africa	833	2,032	4,410	6,000	5	--	30	35	42	75
North Africa and West Asia	2,429	4,510	400	750	7	15	5	10	150	440
South Asia	3,190	5,714	5,136	9,625	1,550	2,500	--	100	--	--
Southeast Asia	73	128	495	850	--	--	40	50	--	--
East Asia & Pac. Is.	13	8	516	725	21	25	594	850	--	--
Total	21,671	32,578	15,563	25,823	3,782	7,995	29,254	55,210	6,526	13,024

Reproduced from World Supply and Demand Prospects for Oilseeds and Oilseed Products in 1980, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 71, March 1971.

Appendix table 17. World Production of Oilcakes by Region and Commodity, Meal-Equivalent Basis, Average 1963-65, and Projections to 1980, and Annual Rate of Change

Region	Copra Meal			Palm Kernel Meal			Cottonseed Meal			Peanut Meal			Linseed Meal		
	1963-65	1980	Annual rate of change	1963-65	1980	Annual rate of change	1963-65	1980	Annual rate of change	1963-65	1980	Annual rate of change	1963-65	1950	Annual rate of change
	1,000 metric tons		Percent	1,000 metric tons		Percent	1,000 metric tons		Percent	1,000 metric tons		Percent	1,000 metric tons		Percent
United States	--	--	--	--	--	--	2,499	2,771	.6	114	190	3.3	447	318	-2.1
Canada	--	--	--	--	--	--							254	215	-1.0
EC	--	--	--	--	--	--	4	--	--	1	--	--	39	46	1.0
United Kingdom	--	--	--	--	--	--									
O.W.E.	--	--	--	--	--	--	147	164	.7	4	5	1.4	3	--	--
Japan	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--
South Africa, Australia-New Zealand	--	--	--	--	--	--	14	42	7.1	56	96	3.4	23	19	-1.2
Total	--	--	--	--	--	--	2,664	2,977	6.3	175	291	3.2	768	598	-1.6
Eastern Europe	--	--	--	--	--	--	12	18	2.6	--	--	--	52	88	3.3
USSR	--	--	--	--	--	--	1,257	1,881	2.6	--	--	--	226	286	1.5
Communist Asia	--	--	--	--	--	--	285	475	3.3	361	669	3.9	--	--	--
Total	--	--	--	--	--	--	1,554	2,377	2.7	361	669	3.9	278	374	1.9
Latin America	102	123	1.2	23	41	3.7	1,063	1,359	1.5	270	478	3.7	519	473	-.6
Africa and West Asia	45	64	2.2	382	434	.8	1,096	2,284	4.7	1,112	1,640	2.5	55	61	.6
Other Asia	1,655	2,369	2.3	35	81	5.4	601	1,978	3.7	1,959	3,451	3.6	--	234	--
Total	1,802	2,556	2.2	440	556	1.5	2,760	4,708	3.4	3,341	5,569	3.2	574	768	1.8
World total	1,802	2,556	2.2	440	556	1.5	6,978	10,062	2.3	3,877	6,529	3.3	1,620	1,740	0.5

--Continued

Appendix table 17. World Production of Oilcakes by Region and Commodity, Meal-Equivalent Basis, Average 1963-65, and Projections to 1980, and Annual Rate of Change continued--

Region	Rapeseed Meal 1963-65	Rapeseed Meal 1980	Rapeseed Meal Annual rate of change	Soybean Meal 1963-65	Soybean Meal 1980	Soybean Meal Annual rate of change	Sunflowerseed Meal 1963-65	Sunflowerseed Meal 1980	Sunflowerseed Meal Annual rate of change	Total 1963-65	Total 1980	Total Annual rate of change
	1,000 metric tons		Percent	1,000 metric tons		Percent	1,000 metric tons		Percent	1,000 metric tons		Percent
United States	--	--	--	15,138	28,541	4.0	--	--	--	18,198	31,820	3.6
Canada	115	498	9.6	124	220	3.6	7	16	5.3	500	949	4.1
EC	193	669	7.9	--	--	--	19	27	2.2	262	742	6.7
United Kingdom	--	--	--	--	--	--	--	--	--	--	--	--
O.W.E.	134	280	4.7	--	--	--	1	5	10.5	289	454	2.9
Japan	68	--	--	--	--	--	--	--	--	70	--	--
South Africa, Australia-New Zealand	--	28	--	--	--	--	46	60	1.7	139	245	3.6
Total	516	1,475	6.8	15,262	28,801	4.0	73	108	2.5	19,458	34,210	3.6
Eastern Europe	318	780	5.8	5	45	14.7	658	1,338	4.5	1,045	2,269	5.0
USSR	4	--	--	140	319	5.3	2,270	3,912	3.5	3,397	6,398	3.1
Communist Asia	353	586	3.2	2,380	3,168	1.8	36	56	2.8	3,415	4,957	2.4
Total	[illegible]	[illegible]	[illegible]	2,525	3,532	2.2	2,964	5,306	3.7	8,357	13,624	3.1
Latin America	34	71	4.7	191	817	9.5	372	1,004	5.3	2,574	4,366	3.4
Africa and West Asia	8	10	1.4	16	19	1.1	87	293	7.9	2,801	4,805	3.4
Other Asia	1,016	1,633	3.0	150	234	2.8	--	--	--	5,416	9,080	3.3
Total	1,058	1,714	3.1	357	1,070	7.1	459	1,297	6.7	10,791	18,251	3.3
World total	2,249	4,722	4.7	18,144	33,377	3.9	3,496	6,711	4.2	38,606	66,085	3.4

Reproduced from World Supply and Demand Prospects for Oilseeds and Oilseed Products in 1980, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 71, March 1971.

Appendix table 18. Oilcakes: World Supply, Demand, and Trade, by Region, Average 1963-65, and Projected to 1980 Under Projection Set I[1/]

Region	Average, 1963-65: Supply	Demand 2/	Export	Import	1980: Supply	Demand	Export	Import	Share of 1980 trade: Import	Export	Annual rate of change, 1963-65 - 1980: Supply	Demand	Trade
	1,000 metric tons				1,000 metric tons				Percent		Percent per year		
United States	18,198	3/11,812	5,904	--	31,820	15,180	16,640	--	--	70.9	3.6	1.6	6.7
Canada	500	880	--	380	949	1,314	--	365	1.6	--	4.1	2.5	-.3
EC	262	5,269	--	5,007	742	10,429	--	9,687	41.2	--	6.7	4.4	4.2
United Kingdom	--	1,619	--	1,619	--	3,190	--	3,190	13.6	--	--	4.3	4.3
[illegible]	289	2,479	--	2,190	454	5,074	--	4,620	19.7	--	2.9	4.6	4.8
Japan	70	1,915	--	1,845	--	4,866	--	4,866	21.7	--	--	6.0	6.2
Australia-New Zealand and South Africa	139	119	20	--	245	215	30	--	--	.1	3.6	3.8	2.6
Total	19,458	4/24,575	5,924	11,041	34,210	40,268	16,670	22,728	96.8	71.0	3.6	3.1	1.1
Eastern Europe	1,045	1,623	--	578	2,269	3,024	--	755	3.2	--	5.0	4.0	1.7
USSR	3,897	3,768	129	--	6,398	6,348	50	--	--	.2	3.1	3.3	-5.8
Communist Asia	3,415	3,333	82	--	4,957	4,507	450	--	--	1.9	2.4	1.9	11.2
Total	8,357	8,724	211	578	13,624	13,879	500	755	3.2	2.1	3.1	3.0	-3.2
Latin America	2,574	1,136	1,438	--	4,366	1,870	2,496	--	--	10.6	3.4	3.2	3.5
Africa and West Asia	2,801	833	1,968	--	4,805	1,335	3,470	--	--	14.8	3.4	3.0	3.6
Other Asia	5,416	4,254	1,162	--	9,080	8,733	347	--	--	1.5	3.3	4.6	-7.3
Total	10,791	6,223	4,568	--	18,251	11,938	6,313	--	--	26.9	3.3	4.2	2.0
World total	38,606	39,522	10,703	11,619	66,085	66,086	23,483	23,483	100.0	100.0	3.4	3.3	--

1/ [illegible] continuation of present production and trade policies (with some modification) and allows for moderate gain in productivity in [illegible].
2/ [illegible] except U.S. are availabilities.
3/ [illegible] stocks.
4/ [illegible] for U.S. stocks.

Reproduced from World Supply and Demand Prospects for Oilseeds and Oilseed Products in 1980, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 71, March 1971.

Appendix table 19. Oilcakes: World Supply, Demand, and Trade, by Region, Average 1963-65, and Projected to 1980 Under Projection Set II[1/]

Region	Average, 1963-65				1980				Share of 1980 trade		Annual rate of change, 1963-65 - 1980		
	Supply	Demand [2/]	Export	Import	Supply	Demand	Export	Import	Import	Export	Supply	Demand	Trade
	1,000 metric tons								Percent		Percent per year		
United States	18,198	3/11,812	5,904	--	31,820	15,633	16,187	--	--	42.8	3.5	1.7	6.5
Canada	500	880	--	380	949	1,547	--	598	2.2	--	4.1	3.6	2.8
EC	262	5,269	--	5,007	742	11,941	--	11,199	41.5	--	6.7	5.3	5.2
United Kingdom	--	1,619	--	1,619	--	3,652	--	3,652	13.5	--	--	5.2	5.2
O.W.E.	289	2,479	--	2,190	454	5,884	--	5,430	20.1	--	2.7	5.5	5.2
Japan	70	1,915	--	1,845	--	5,014	--	5,014	18.6	--	--	6.2	6.4
Australia-New Zealand & South Africa	139	119	20	--	245	245	--	--	--	--	3.6	4.6	--
Total	19,458	4/24,575	5,924	11,041	34,210	43,916	16,187	25,893	96.0	42.8	3.6	3.7	4.1
Eastern Europe	1,045	1,623	--	578	2,269	3,356	--	1,087	4.0	--	5.0	4.7	4.0
USSR	3,897	3,768	129	--	6,398	6,348	50	--	--	16.9	3.1	3.3	-5.8
Communist Asia	3,415	3,333	82	--	4,957	4,507	450	--	--	13.1	2.3	1.9	11.2
Total	8,357	8,724	211	578	13,624	14,211	500	1,087	4.0	30.0	3.1	3.1	3.0
Latin America	2,574	1,136	1,438	--	5,432	2,042	3,390	--	--	9.0	4.8	3.7	5.5
Africa and West Asia	2,801	833	1,968	--	6,065	1,336	4,729	--	--	12.5	5.0	3.0	5.7
Other Asia	5,416	4,254	1,162	--	11,013	8,839	2,174	--	--	5.7	4.5	4.7	4.0
Total	10,791	6,223	4,568	--	22,509	12,217	10,292	--	--	27.2	4.7	4.3	5.2
World total	38,606	39,522	10,705	11,619	70,344	70,344	26,980	26,980	100.0	100.0	3.8	3.4	--

1/ Set II assumes that agricultural productivity and economic growth in the LDC's would be higher than projected in set I.
2/ All regions except U.S. are availabilities.
3/ Does not include stocks.
4/ Includes an allowance for U.S. stocks.

Reproduced from World Supply and Demand Prospects for Oilseeds and Oilseed Products in 1980, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 71, March 1971.

Appendix table 20. Oilcakes: World Supply, Demand, and Trade, by Region, Average 1963-65, and Projected to 1980 Under Projection Set III1/

Region	Average, 1963-65				1980				Share of 1980 trade		Annual rate of change, 1963-65 – 1980		
	Supply	Demand 2/	Export	Import	Supply	Demand	Export	Import	Import	Export	Supply	Demand	Trade
	1,000 metric tons								Percent		Percent per year		
United States	18,198	3/11,812	5,904	—	31,820	14,890	16,930	—	—	76.7	3.6	1.4	6.8
Canada	500	880	—	380	949	1,166	—	217	1.0	—	4.1	1.8	-3.5
[illegible]	262	5,269	—	5,007	742	9,464	—	8,722	39.5	—	6.7	3.7	3.6
United Kingdom	—	1,619	—	1,619	—	2,897	—	2,897	13.1	—	—	3.7	3.7
O.W.E.	289	2,479	—	2,190	454	4,557	—	4,103	18.6	—	2.9	3.9	4.0
Japan	70	1,915	—	1,845	—	4,771	—	4,771	21.6	—	—	5.9	6.1
Australia-New Zealand & South Africa	139	119	20		245	196	49	—	—	.2	3.6	3.2	5.8
Total	19,458	4/24,575	5,924	11,041	34,210	37,941	16,979	20,710	93.8	76.9	3.6	2.8	-1.9
Eastern Europe	1,045	1,623	—	578	2,269	2,812	—	543	2.5	—	5.0	3.5	-.4
USSR	3,897	3,768	129	—	6,398	6,348	50	—	—	.2	3.1	3.3	-5.8
Communist Asia	3,415	3,333	82	—	4,957	4,507	450	—	—	2.1	2.4	1.9	11.2
Total	8,357	8,724	211	578	13,624	13,667	500	543	2.5	2.3	3.1	2.8	5/
Latin America	2,574	1,136	1,438	—	3,563	1,761	1,802	—	—	8.2	2.1	2.8	1.5
Africa and West Asia	2,801	833	1,968	—	4,122	1,334	2,788	—	—	12.6	2.4	3.0	2.2
Other Asia	5,416	4,254	1,162	—	7,849	8,665	—	816	3.7	—	2.3	4.6	—
Total	10,791	6,223	4,568	—	15,534	11,760	4,590	816	3.7	20.8	2.3	4.1	-.5
World total	38,606	39,522	10,703	11,619	63,368	63,368	22,069	22,069	100.0	100.0	3.1	3.0	—

1/ Set III assumes that agricultural productivity and economic growth in the LDC's would be lower than projected under set I.
2/ All regions except U.S. are availabilities.
3/ Does not include stocks.
4/ Includes an allowance for U.S. stocks.
5/ Net trade declines by more than 15 percent.

Reproduced from World Supply and Demand Prospects for Oilseeds and Oilseed Products in 1980, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 71, March 1971.

Appendix table 21. Japan's Domestic and Imported Grain 1/ Usage: 1965 Actual and 1985 Estimated Requirements to Meet Food Consumption Targets of Alternative Food Strategies 2/

Usage	Actual, 1965 3/			Estimated requirements, 1985 4/								
				Western strategy			Pacific strategy			Eastern strategy		
	Domestic	Imported	Total	Domestic	Imported	Total	Domestic	Imported	Total	Domestic	Imported	Total
	Million metric tons											
Milling for food 5/	12.8	3.5	16.3	7.0	7.3	14.3	10.8	5.9	16.7	11.9	5.1	16.9
Livestock feed 6/	.5	5.5	6.0	1.0	40.8	41.8	1.0	16.9	17.9	1.1	12.4	13.5
Manufacturing, seed, and waste	7/ 1.9	7/ 1.3	7/ 3.2	1.8	2.0	3.9	2.0	1.6	3.6	2.0	1.4	3.4
Total usage, or total new supply	15.2	10.3	25.5	9.8	50.2	60.0	13.9	24.4	38.2	15.0	18.8	33.8

1/ All grains, that is, rice, wheat, barley, corn, grain sorghums, oats, rye, millet, and buckwheat.

2/ How much raw grain would be needed to achieve the food consumption targets for the respective strategies, and under the agricultural and trade policies applicable to each? The assumed food consumption targets for 1985 are shown in tables 8, 9 and 10. The estimated per capita grain requirements to meet these targets are in appendix II, and are converted to tonnages by multiplying by 120 million, the population projected for 1985 by Japan's Economic Planning Agency in 1968.

3/ From Japanese Ministry of Agriculture and Forestry's Food Balance, 1965. See Abstract of Statistics on Agriculture, Forestry and Fisheries: Japan, 1966.

4/ Grain tonnages for milling and feed are estimated as shown in tables 15 to 20, appendix II. Although not shown here, the following estimates are made by individual grain: Manufacturing tonnages are "educated guesses". Waste tonnages at 2 percent of milling, feed and manufacturing totals. Seed tonnages at the following percentages of milling, feed, manufacturing and waste domestic totals: Rice 0.8 percent, barley 1.7 percent, others 2 percent.

5/ Tonnages are gross food basis, that is, weight of unmilled grain for food (not including grain wasted) even though brans and byproducts not consumed by humans are thereby included.

6/ Does not include brans and food milling byproducts destined for animal feeding. For the estimated requirement columns, tonnages are feed values in corn units. Actual weight of raw feed grain would probably be higher on the assumption of large usage of sorghums and barley, of lower feeding value than corn per unit of weight. See tables 18-20, appendix II.

7/ Includes 1965 net addition to stocks of grain.

Details may not add to totals because of rounding.

Reproduced from Japan's Food Demand and 1985 Grain Import Prospects, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 53, Washington, D.C., June 1969.

ANNEX A-7. U.S. EXPORTS OF PHOSPHATE ROCK

CONTENTS

INTRODUCTION

Phosphate rock is the term used to describe rock containing one or more phosphate minerals of sufficient and suitable composition to permit its use, either directly or after concentration, in manufacturing commercial products, i.e., fertilizer, animal feed, detergents, and chemical polishers. Phosphorus pentoxide (P_2O_5) contains 43.64 percent phosphorus and by convention is used to express the phosphorus content of fertilizer and phosphate rock, which varies among different supply sources.

Phosphates are used primarily for fertilizers both in the United States and abroad. However, there are discrepancies in data sources on the amounts of phosphate rock and phosphate materials used for different purposes. For 1968 the Bureau of Mines estimated that 76 percent of phosphate rock sold or used was for fertilizer, 3 percent was for animal and fowl feed, and the remaining 21 percent was for industrial or other end use categories.1/ This is consistent with the data published regularly in the Minerals Yearbook, which show that the P_2O_5 content of phosphate rock sold or used by producers for agricultural uses is 77 to 79 percent of total uses. However, the Bureau of Mines figures on P_2O_5 sold or used for fertilizer are far greater than similar figures published by the Department of Agriculture (USDA). The Bureau of Mines estimated 6.0 million

1/ Richard W. Lewis, "Phosphorus," in U.S. Department of the Interior, Mineral Facts and Problems, 1970 ed., Bureau of Mines Bulletin 650 (Washington, D.C.: Government Printing Office, 1970), p. 1139.

tons[1] of P_2O_5 were used for fertilizer in 1969, compared with USDA's estimate of 4.6 million tons.[2]

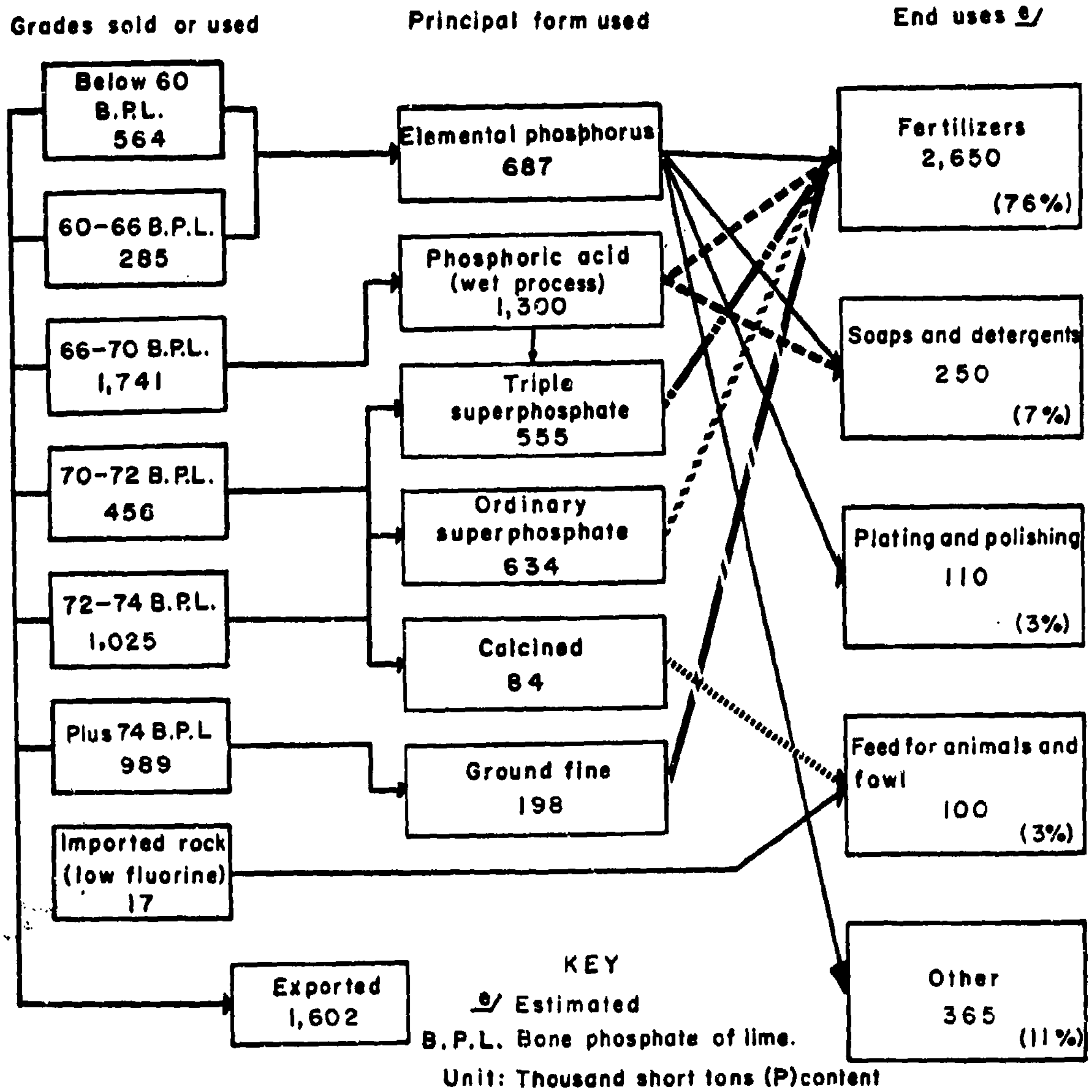
The reason for this large difference lies initially in sources of basic data. The USDA data represent wholesale and/or retail sales of phosphate fertilizers and are based on data from state fertilizer sales tax sources. The Bureau of Mines obtains its figures from questionnaires filled out by the producers of phosphate rock. The producers estimate the amount of phosphate rock used or sold for agricultural, industrial, export, and other end uses, based on their own sales of rock or processed phosphatic materials.

Mr. Richard Lewis, author of the chapter on phosphorus in the Bureau of Mines Mineral Facts and Problems, has found that the end use data as compiled from producers' reports are inaccurate.[3] Basic reasons are the lack of uniformity among producers in interpreting and answering the questionnaire, inadequate knowledge by phosphate producers of actual end use, and other factors. Neither the Bureau of Mines nor the USDA source takes into account changes in stocks, which could be a large item in the whole production, processing, and distribution chain. Also, the Bureau of Mines, in estimating apparent U.S. consumption of P_2O_5, does not take into account imports and exports of phosphate materials such as superphosphate, ammonium phosphate, and phosphoric acid.

In addition, wholesale and retail sales of fertilizer are less than sales and uses of P_2O_5 as reported by phosphate rock producers because of losses in processing and shipment. As shown in figure 1, virtually all phosphate rock is processed into various phosphorus

1/ U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook 1969, Washington, D.C., p. 912.
2/ U.S. Department of Agriculture, Economic Research Service, Fertilizer Situation, Washington, D.C., March 1971, p. 8.
3/ Based on telephone conversation with Mr. Lewis.

Figure 1. Material Forms Flow for Phosphorus Materials, 1968



Source: Richard W. Lewis, "Phosphorus," in U.S. Department of the Interior, Mineral Facts and Problems, 1970 ed., Bureau of Mines Bulletin 650 (Washington, D.C.: Government Printing Office, 1970), p. 1147.

materials for end use consumption, most of which are used for fertilizer. One industry source states that P_2O_5 losses in processing rock into phosphoric acid and other materials might be 8 to 12 percent.1/ If this loss rate applied to all processing, it would account for nearly half of the difference between the quantities used for fertilizer reported by USDA and the Bureau of Mines. If a further adjustment is made for net exports of P_2O_5 in fertilizer materials, most of the remaining difference is accounted for.

Hence it is concluded that the Bureau of Mines data are a reasonable guide to the proportionate demand for phosphate rock production by P_2O_5 end use category, but that they must be adjusted for exports of phosphate fertilizer materials and for losses in fertilizer manufacture (table 1).

1/ Information obtained by telephone conversation with John F. Gale, U.S. Department of Agriculture, Economic Research Service.

Table 1. Reconciliation of Data from Bureau of Mines and U.S. Department of Agriculture on Use of P_2O_5 for Fertilizer in the United States

P_2O_5 use	Thousands of short tons
Bureau of Mines	
P_2O_5 content of phosphate rock sold or used for agricultural purposes in 1969....	5,958
Less:	
Estimated losses of P_2O_5 in manufacture of fertilizer materials (12 percent)..................	714
Net exports of P_2O_5 as fertilizer materials.......	531
Estimated use for feed......	200
Balance......................	4,513
USDA	
P_2O_5 consumption as fertilizer in the United States:	
Crop year 1968-69............	4,636
Crop year 1969-70............	4,576
Two-year average............	4,606

Source: P_2O_5 content of phosphate rock -- U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook 1969. Net exports of P_2O_5 -- Tennessee Valley Authority, National Fertilizer Development Center, Fertilizer Trends - 1971, by Edwin A. Harre, Bulletin Y-40 (Muscle Shoals, Alabama: TVA, December 1971). P_2O_5 consumption -- U.S. Department of Agriculture, Economic Research Service, Fertilizer Situation, March 1971.

I. STRUCTURAL AND GEOGRAPHICAL CHARACTERISTICS OF PHOSPHATE ROCK PRODUCTION AND EXPORTS

Although a total of 23 states are reported as having phosphate rock deposits, there are presently only four commercial-grade phosphate reserve areas in the United States: Florida, North Carolina, Tennessee, and the West (Idaho, Montana, Utah, and Wyoming).

Table 2 lists phosphate rock producing companies by mine location and capacity. Most of the mining companies beneficiate and process rock to a marketable product. However, a few sell rock to other companies for processing. Most major producers manufacture phosphatic fertilizers or elemental phosphorus, usually in plants near the mining operations.1/

The location and type of phosphate deposits have influenced the growth of the industry in the four major areas (table 3). The Western phosphates account for approximately 42 percent of U.S. known commercial-grade reserves in an area of some 135,000 square miles, extending from northern Utah for about 500 miles through Idaho, Wyoming, and into Montana. The phosphate occurs as soft weathered shales that are greatly compressed and folded, so that beds often dip sharply. The thicker and higher grade deposits are workable only by underground mining. Although the Western reserve area is one of the largest phosphate fields in the

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1/ Richard W. Lewis, "Phosphorus," in Mineral Facts and Problems, 1970 ed., Bureau of Mines Bulletin 650, p. 1140.

Table 2. U.S. Producers of Phosphate Rock
(In thousands of short tons)

State and company	Location of mines	1970 year-end capacity
Florida[a]		
Agrico Chemical (Conoco)........	Palmetto, Bradley, Pierce	6,500
Brewster Phosphates (American Cyanamid)....................	Chicora, Brewster	3,650
Davison Chemical (W.R. Grace)...	Bonnie Lake	1,550
International Minerals & Chemicals....................	Achan, Noralyn, Mulberry, Kingsford, Bonnie	8,000
Mobil Chemical..................	Clear Springs, Fort Meade	5,700
Occidental Agricultural.........	White Springs	3,000
Smith-Douglass (Borden).........	Tenorac	1,500
Swift..........................	Watson, Silver City	3,000
Tennessee Corporation (Cities Service)......................	Fort Meade	2,000
USS Agri-Chemicals (Armour).....	Armour, Fort Meade	3,500
Subtotal.....................		38,400
California		
Cuyama Phosphate Corporation....	Cuyama	300
Idaho		
El Paso Natural Gas Company.....	Soda Springs	400
Monsanto.......................	Ballard	1,000

continued--

Table 2. U.S. Producers of Phosphate Rock continued--

(In thousands of short tons)

State and company	Location of mines	1970 year-end capacity
Mountain Fuel Supply Company......	Conda	250
San Francisco Chemical (Stauffer).	Montpelier, Soda Springs	200
J.R. Simplot......................	Fort Hall, Soda Springs	1,000
Subtotal........................		2,850
Montana		
Cominco American..................	Garrison, Douglas	750
George Relyea.....................	Garrison	100
Stauffer Chemical Company.........	Melrose	600
Subtotal........................		1,450
North Carolina		
Texas Gulf Sulphur Corporation....	Lee Creek (Aurora)	3,000
Tennessee		
Hooker Chemical...................	Columbia	750
Mobil Chemical....................	Mt. Pleasant	200
Monsanto..........................	Columbia	1,000
Presnell Phosphate................	Columbia	700
Tennessee Valley Authority........	Franklin, Knob Creek	200
USS Agri-Chemicals................	Columbia	90
Victor Chemicals (Stauffer).......	Mt. Pleasant	600
Subtotal........................		3,540

continued--

Table 2. U.S. Producers of Phosphate Rock continued--

(In thousands of short tons)

State and company	Location of mines	1970 year-end capacity
Utah		
San Francisco Chemicals (Stauffer).	Cherokee, Vernal	600
Wyoming		
San Francisco Chemicals (Stauffer).	Leefe	500
Total United States................		50,640

a/ All listed Florida producers mined land-pebble phosphate. In addition, there were six other companies that produced "soft" or "waste-pond" phosphate in amounts totaling about 39,200 short tons per year. There were no producers of hard-rock phosphate.

Source: Compiled from Tennessee Valley Authority, National Fertilizer Development Center, Fertilizer Trends -- 1969, by Edwin A. Harre (Muscle Shoals, Alabama: TVA, 1970), p. 37; and Tennessee Valley Authority, Office of Agricultural and Chemical Development, Division of Chemical Development, The Phosphate Industry in the United States (Muscle Shoals, Alabama: TVA, 1970).

Table 3. Reserves and Potential Reserves of Phosphate Minerals in the United States

(In millions of short tons)

Source	Known reserves		Potential reserves	
	Marketable product	P content	Marketable product	P content
Alabama........	--	--	n.a.	n.a.
Arkansas.......	--	--	20	2
California.....	n.a.	n.a.	n.a.	n.a.
Florida........	2,250	315	26,000	2,400
Georgia........	--	--	n.a.	n.a.
North Carolina.	2,240	290	n.a.	n.a.
Tennessee......	65	5	6,000	550
Western field:				
Idaho.........	1,340	145	6,700	740
Montana.......	1,100	110	1,400	150
Utah and Wyoming......	900	170	14,300	1,940
Total........	7,895	1,035	54,420	5,782

n.a. = not available.

Source: Richard W. Lewis, "Phosphorus," in U.S. Department of the Interior, Mineral Facts and Problems, 1970 ed., Bureau of Mines Bulletin 650 (Washington, D.C.: Government Printing Office, 1970), p. 1143.

world, its development has been limited because of the expense of underground mining. (The three other areas of the United States use relatively inexpensive strip mining.) However, it has a locational advantage in the Western agricultural market as well as in Canada. In 1969, 12 percent of Western production was exported to Canada, 66 percent went to industrial uses, and the balance went to agriculture.

North Carolina has approximately 28 percent of U.S. commercial-grade phosphate ore, located in Beaufort County near the Pamlico Sound in eastern North Carolina (figure 2). Large-scale mining began in 1966. Present production capacity is 3 million tons, with an expansion capability to 9 million tons.1/ However, in North Carolina restrictions on water usage in the mining of phosphate have been proposed. These restrictions, if passed into state law, could limit current mining operations and prevent expansion in the future.2/

Tennessee has only 1 percent of total commercial-grade reserves. It is an important producer despite its relatively small reserves. Although it has three types of phosphate rock, only one is currently being mined. Mining is done by drag-line, as in Florida, but on a smaller scale. All Tennessee phosphate is used for industrial purposes.3/

Florida has approximately 28 percent of U.S. commercial-grade phosphate reserves and accounts for nearly 80 percent of U.S. phosphate rock marketable production. In 1969, 61 percent of its production was used in agriculture and 38 percent was exported. The phosphate deposits are located in two areas: one is east

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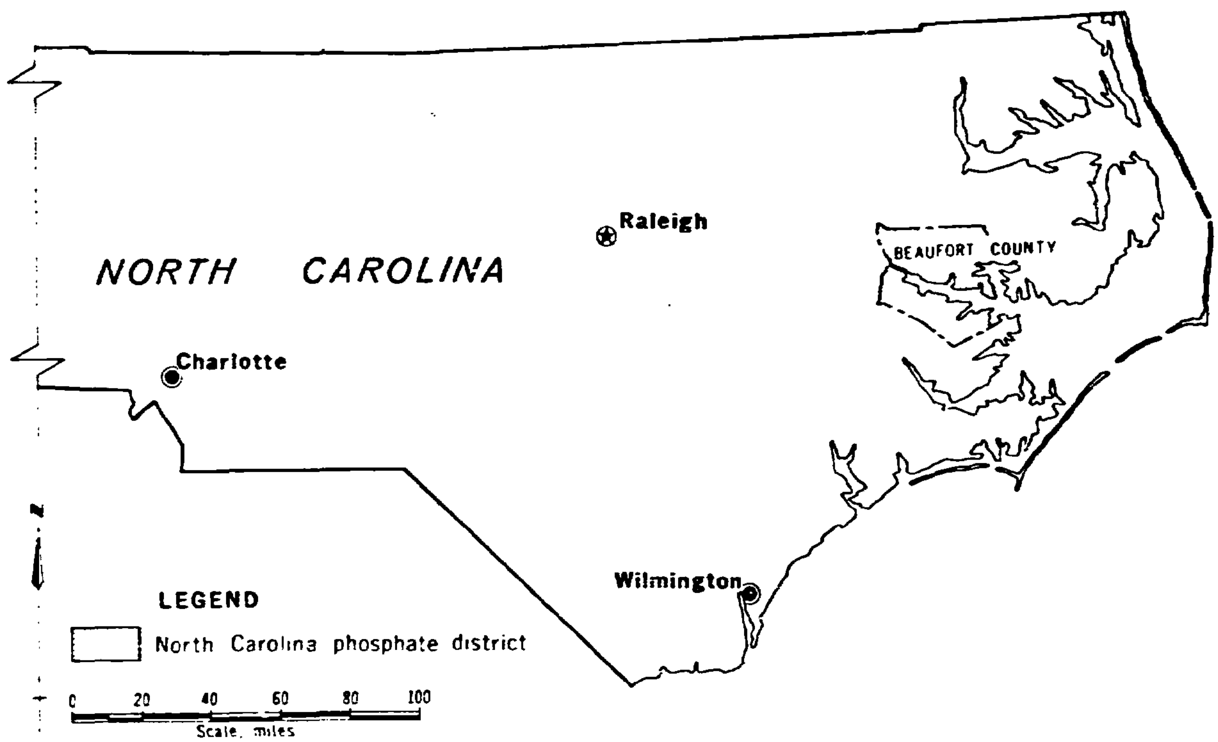
1/ U.S. Army Corps of Engineers, Review Report, Pamlico River and Morehead City Harbor, Wilmington District, 1970.

2/ Richard W. Lewis, "Phosphorus," in Mineral Facts and Problems, 1970 ed., Bureau of Mines Bulletin 650, p. 1154.

3/ Bureau of Mines, Minerals Yearbook 1969, p. 912.

Figure 2. North Carolina Phosphate District



Source: U.S. Department of the Interior, The Phosphate Industry in the Southeastern United States and Its Relationship to World Mineral Fertilizer Demand, by John W. Sweeney and Robert N. Hasslacher, Bureau of Mines Information Circular 8459 (Washington, D.C.: Government Printing Office, 1970), p. 14.

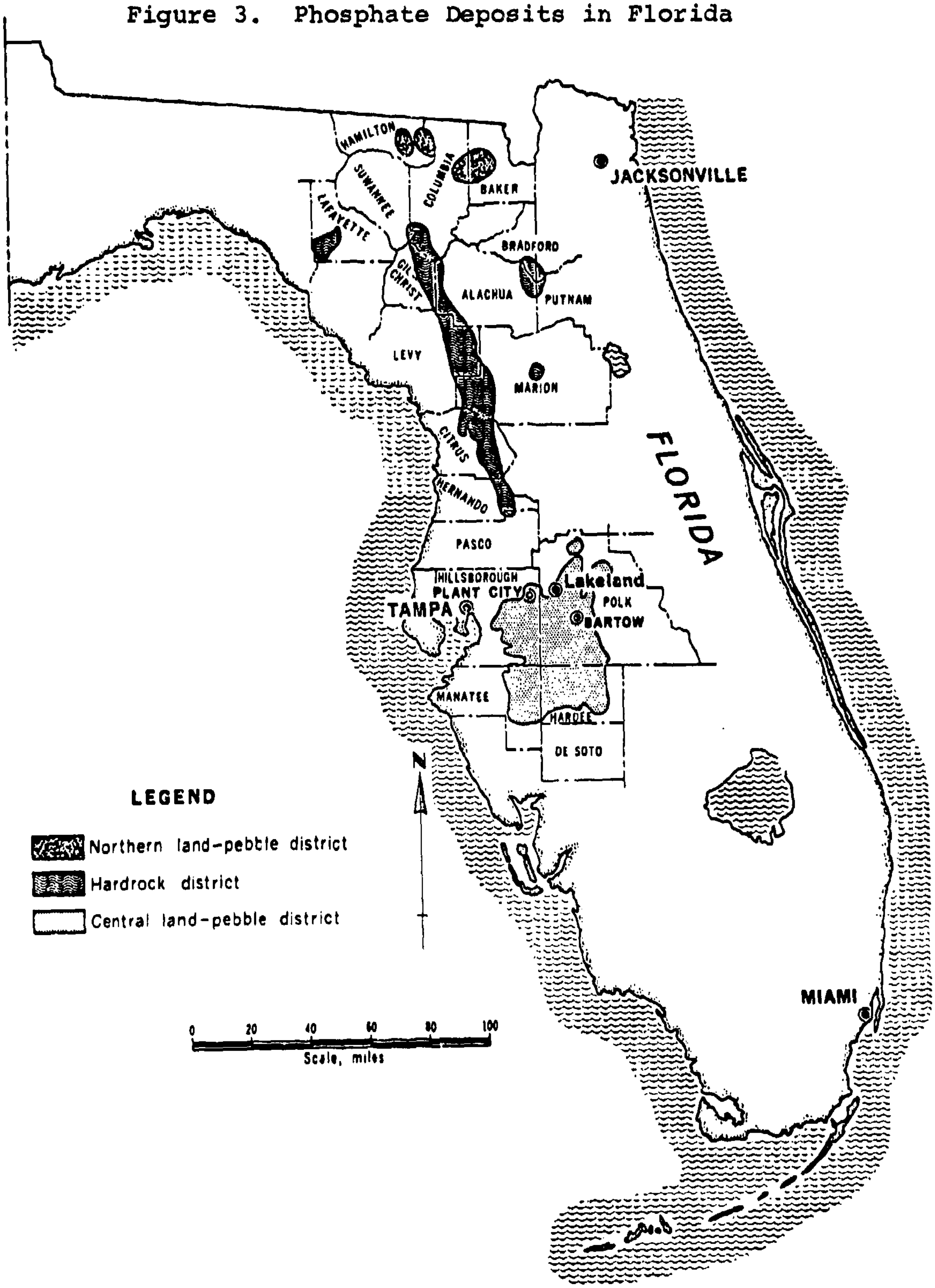
of Tampa, and is approximately 40 miles wide by 50 miles long; the second is directly west of Jacksonville (figure 3). Practically all of Florida's phosphate rock production is from land pebble phosphate. The hard-rock phosphate occurs in an area about 100 miles long and 3 to 30 miles wide, extending from Tampa north to the Lake City area near Jacksonville. The availability of more easily minable land pebble has held back commercial development of hard-rock phosphate, production of which was discontinued in 1966.1/

In 1969, 97 percent of all U.S. phosphate rock waterborne exports were from Florida (table 4). The principal ports accounting for this percentage were Tampa with 82 percent, Jacksonville with 8 percent, and Boca Grande with 7 percent. As of 1969 plans were made to discontinue phosphate loading at Boca Grande with the completion of new loading facilities at Tampa.2/ The slightly increased production in the Jacksonville area, as well as the increasing shipments through Tampa, are expected to account for most of U.S. oceanborne export rock movement in the future.

The low inland transport cost due to proximity to port, relatively inexpensive mining methods, size of reserves, and established port handling facilities indicate that Tampa's primary position as an exporter is not threatened in the foreseeable future by any domestic competitor. This conclusion is reinforced by the above-mentioned constraints on production in North Carolina, and the fact that f.o.b. port values for phosphate rock shipped from Tampa are lower than shipments from North Carolina ($7.28 per short ton from Tampa in 1969 compared with $7.93 from North Carolina). In addition the P_2O_5 content of Florida rock is higher than North Carolina.

1/ Tennessee Valley Authority, Office of Agricultural and Chemical Development, Division of Chemical Development, The Phosphate Industry in the United States, by E.C. Houston (Muscle Shoals, Alabama: TVA, July 1970), pp. 1 and 2.
2/ U.S. Army Corps of Engineers, Survey Report on Tampa Harbor, Jacksonville District, 1969.

Figure 3. Phosphate Deposits in Florida



Source: U.S. Department of the Interior, The Phosphate Industry in the Southeastern United States and Its Relationship to World Mineral Fertilizer Demand, by John W. Sweeney and Robert N. Hasslacher, Bureau of Mines Information Circular 8459 (Washington, D.C.: Government Printing Office, 1970), p. 10.

Table 4. Waterborne U.S. Exports of Phosphate Rock by Port of Shipment

Port	1968		1969	
	Short tons	Percent	Short tons	Percent
	(1,000)		(1,000)	
Tampa.............	8,804	83.0	8,198	82.1
Jacksonville......	907	8.5	811	8.1
Boca Grande.......	712	6.7	712	7.1
Beaufort-Morehead.	69	.7	258	2.6
Norfolk...........	68	.6	--	--
Baltimore.........	19	.2	--	--
New Orleans.......	12	.1	--	--
Other.............	21	.2	14	.1
Total..........	10,612		9,993	

Source: RRNA tabulation from data in U.S. Bureau of the Census, U.S. Waterborne Merchandise Exports, SA-705, Annual.

Recently five Florida phosphate rock producers, reported to account for about three-fourths of total U.S. exports, formed the Phosphate Rock Export Association under the Webb-Pomerene Act. The member companies are American Cyanamid, Continental Oil, W.R. Grace, International Minerals and Chemicals, and Occidental Chemicals. This association will function as a combined export entity on behalf of the member companies, with responsibilities for marketing, sales, pricing, and shipping arrangements. Its purpose is to eliminate price competition in the export market among the members themselves, to enhance their negotiating and bargaining position, to reduce marketing costs, and to achieve economies in ocean transport which the consolidation of the export business of the five member companies should permit.

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II. WORLD PRODUCTION, CONSUMPTION, AND RESERVES OF PHOSPHATE ROCK

Tables 5 and 6 show production of phosphate rock by country on an actual weight basis and the estimated P_2O_5 content of rock produced for selected years, starting with 1955. Table 5 also shows the average P_2O_5 content of rock produced by country. In terms of the competitive position of the United States in world markets, it is important to note that the average P_2O_5 content for the United States at 31.0 percent is the lowest of all major producers, and compares with 39.6 percent for Tunisia, 33.3 percent for Morocco, 38.0 percent for the islands in the Indian and Pacific Oceans, and 35.4 percent for South Africa.

The importance of the United States as a world producer is evident from its relationship to the world total (42 percent of world production in 1969) and its superior rate of growth during 1955-69 (7.5 percent annually compared with 7.3 percent worldwide). On the other hand, the developing countries more than doubled their production during 1955-69 and accounted for nearly one-third of the world total in 1969. This production was heavily concentrated in Morocco and in other African and Mediterranean countries. Most of the balance of world production was in the U.S.S.R., whose growth rate during the period was 11.1 percent.

The U.S. position vis-a-vis the rest of the world is somewhat different, however, with respect to quantity of reserves of phosphate rock. As shown in table 7, the United States has less than 8 percent of the world known marketable reserves of phosphate rock. Over 67 billion tons of a world total of 103.6 billion

Table 5. Production of Phosphate Rock, 1955-70, Actual Weight

Country	Average P_2O_5 content, 1969	1955	1960	1965	1968	1969	1970	Rate of change, 1955-69
	(pct.)	------------		thousands tons			------------	(%/yr.)
World	32.8	28,915	39,714	60,324	79,309	76,968	n.a.	7.2
Developing countries	34.0	11,965	14,626	20,210	24,179	23,649	23,900[a]	5.0
Algeria	33.4	752	563	86	361	428	499	-3.9
Israel	33.4	72	224	414	902	1,120	880[a]	
Jordan	32.8	164	362	828	1,162	1,094	891	14.5
Morocco	33.3	5,329	7,506	9,807	10,519	10,662	11,400	5.1
Senegal	36.6	110	213	1,038	1,270	1,201	998	18.6
Togo	36.9	--	--	974	1,375	1,473	1,508	n.a.
Tunisia	39.6	2,201	2,101	3,041	3,456	2,600	3,024	1.2
UAR	29.8	647	566	594	681	560	n.a.	-1.0
Islands in the Indian and Pacific Oceans[b]	38.0	2,448	2,639	3,022	4,014	3,985	3,601[a]	3.5
Others	32.1	252	452	406	439	527	n.a.	5.4
Developed market economy countries	31.1	12,722	18,177	27,426	38,624	35,615	n.a.	7.6
United States	31.0	12,461	17,796	26,746	37,423	34,224	28,294[a]	7.5
South Africa	35.4	136	268	610	1,111	1,271	1,251	17.3
Others	21.7	125	113	70	90	120	n.a.	-0.3

continued--

Table 5. Production of Phosphate Rock, 1955-70, Actual Weight continued--

Country	Average P_2O_5 content, 1969	1955	1960	1965	1968	1969	1970	Rate of change, 1955-69
	(pct.)	------------		thousands tons		------------		(%/yr.)
Socialist countries.	34.6	4,218	6,911	12,686	16,506	17,704	n.a.	10.8
U.S.S.R............	35.1	3,868	5,629	10,945	14,894	15,745	n.a.	10.5
Others.............	30.0	350	1,282	1,743	1,612	1,959	n.a.	13.1

a/ Partly estimated.
b/ Christmas, Makatea, Nauru and Ocean Islands.

Source: United Nations, Conference on Trade and Development, International Action on Commodities in the Light of Recent Developments (TD/B/C.1/88/Rev. 1), 30 April 1971, Annex, table 1, p. 2.

Table 6. Production of Phosphate Rock, 1955-69, P_2O_5 Content

Country	1955	1960	1965	1968	1969	Rate of change, 1955-69
	---------- thous. tons -------------					(%/yr.)
World................	9,372	12,936	19,752	25,886	25,223	7.3
Developing countries.	3,961	4,908	6,852	8,168	8,029	5.2
Algeria.............	224	167	25	121	143	-3.2
Israel..............	20	64	124	299	374	23.0
Jordon..............	55	119	269	380	359	14.3
Morocco.............	1,759	2,529	3,296	3,503	3,551	5.2
Senegal.............	33	72	379	466	439	20.0
Togo................	--	--	360	507	544	n.a.
Tunisia.............	655	625	918	1,023	769	1.2
UAR.................	184	163	174	203	167	-0.7
Islands in the Indian and Pacific Oceans a/...........	953	1,028	1,179	1,525	1,514	3.4
Others..............	78	141	128	141	169	5.7
Developed market economy countries...	4,002	5,627	8,511	12,051	11,076	7.5
United States.......	3,949	5,530	8,291	11,651	10,600	7.3
South Africa........	27	75	206	380	450	22.0
Others..............	26	22	14	20	26	--
Socialist countries..	1,409	2,401	4,389	5,667	6,118	11.1
U.S.S.R.............	1,304	1,996	3,853	5,193	5,530	10.9
Others..............	105	405	536	474	588	13.1

a/ Christmas, Makatea, Nauru and Ocean Islands.

Source: United Nations, Conference on Trade and Development, International Action on Commodities in the Light of Recent Developments (TD/B/C.1/88/Rev. 1), 30 April 1971, Annex, table 2, p. 3.

Table 7. World Known Marketable Reserves of Phosphate Rock

Country	Million short tons
United States....................	7,850
Morocco..........................	33,000
Spanish Sahara..................	29,500
Tunisia..........................	5,000
Senegal..........................	35
Togo.............................	110
Other free world................	5,055
U.S.S.R.........................	18,000
Other Communist World...........	5,000
Total..........................	103,555

Source: Data received during telephone conversation of March 3, 1972, from Mr. Stowasser, U.S. Department of the Interior, Bureau of Mines.

tons are in the North African countries of Morocco, Spanish Sahara, and Tunisia. Most of the balance is in the U.S.S.R. and other Communist countries.

Consumption of phosphate rock is heavily concentrated in the developed countries, including the U.S.S.R. (60.4 million tons of a world total of 75.1 million). Nearly a third of the world total is consumed in the United States, and nearly one-quarter is consumed in Western Europe. Only 5.1 million tons were consumed by the non-Socialist developing countries. However, the annual average rate of growth of consumption in the latter group in 1955-69 was 11.0 percent compared with 5.4 percent in the non-Socialist developed countries (table 8).

Table 8. Apparent Consumption of Phosphate Rock, 1955-69

Country	1955	1960	1965	1968	1969	Rate of change, 1955-69
	------- thous. tons, actual weight --					(%/yr.)
World................	29,760	39,302	59,639	74,927	75,056	6.8
Developed market economy countries...	24,126	29,929	42,659	51,831	50,294	5.4
European Economic Community..........	4,821	6,390	9,279	11,251	11,330	6.3
United Kingdom......	1,114	1,395	1,711	1,870	1,648	2.8
Other Western European countries....	2,209	2,816	3,683	4,574	4,511	5.2
Australia...........	1,420	1,562	2,689	3,626	2,672	4.6
Canada..............	539	855	1,365	2,029	1,921	9.5
New Zealand.........	589	563	888	957	1,047	4.2
South Africa........	497	706	730	1,074	1,034	5.4
United States.......	11,280	13,551	19,837	22,985	23,161	5.3
Japan...............	1,657	2,091	2,477	3,465	2,970	4.3
Developing countries.	1,184	1,750	3,108	4,810	5,119	11.0
Brazil..............	168	313	283	498	452	7.3
India...............	66	285	577	942	735	18.8
Republic of Korea...	6	10	7	429	572	39.0
Mexico..............	46	93	251	352	788	23.0
Morocco.............	95	71	229	548	465	12.0
Tunisia.............	212	290	661	771	699	8.9
Others..............	591	688	1,100	1,270	1,408	6.4

continued--

Table 8. Apparent Consumption of Phosphate Rock, 1955-69 continued--

Country	1955	1960	1965	1968	1969	Rate of change, 1955-69
	------ thous. tons, actual weight --					
Socialist countries..	4,450	7,623	13,872	18,286	19,643	11.2
U.S.S.R..............	2,879	3,711	7,370	9,725	10,090	9.4
China (mainland)....	250	1,455	1,664	2,095	2,452	17.7
Poland..............	464	651	1,253	1,612	1,910	10.6
Germand Democratic Republic...........	265	508	809	1,201	1,264	11.8
Others..............	592	1,298	2,776	3,653	3,927	14.5

Source: United Nations, Conference on Trade and Development, International Action on Commodities in the Light of Recent Developments (TD/B/C.1/88/Rev. 1), 30 April 1971, Annex, table 3, p. 4.

III. INTERNATIONAL TRADE IN PHOSPHATE ROCK

The evolution of phosphate rock export trade in 1955-70 by country of origin is shown in table 9. Dynamic growth was registered during this period -- principally by Morocco, whose volume of exports has usually exceeded that of the United States; by the U.S.S.R.; and by the United States, whose exports rose from 2.3 million to 10.4 million tons. Developing country exports rose from 11.1 to 21.6 million tons.

As shown in table 10, world imports of phosphate rock in 1969 were 37.0 million tons, of which 7.7 million were imports by Socialist countries, leaving a balance of 29.3 million. Of that balance, 17.4 million was imported by Western Europe and about 3 million by Japan. Imports by non-Socialist developing countries were approximately 10 percent of total non-Socialist country imports.

Socialist countries took over half of their imports from developing countries in the non-Socialist group. Imports from the United States by the non-Socialist group were about one-third of their total imports, of which about a third was taken by EEC countries, nearly 20 percent by Japan, and about 20 percent by other developed market economy countries (mainly Canada). The United States was not strong in the United Kingdom or other Western European countries, where it supplied less than 10 percent of phosphate rock imports, compared with 30 percent of the EEC market and 63 percent of the Japanese market. It also supplied one-third of the imports of developing countries.

Table 9. Exports of Phosphate Rock, 1955-70

Country	1955	1960	1965	1968	1969	1970	Rate of change; 1955-69
	---------- thous. tons, actual weight --------						(%/yr.)
World	14,373	19,949	29,014	37,642	36,990	37,960[a/]	7.0
Developing countries	11,084	13,349	18,262	21,576	21,239	21,598[a/]	4.8
Algeria	682	471	55	252	360	452	-4.5
Israel	--	95	301	729	870	760	n.a.
Jordan	151	329	605	1,095	928	658	13.8
Morocco	5,251	7,526	9,553	10,094	10,264	11,314	4.9
Senegal	85	176	922	1,025	1,010	1,056[a/]	19.3
Togo	--	--	982	1,357	1,464	1,517	n.a.
Tunisia	1,900	1,641	2,308	2,460	1,855	2,109	-0.2
UAR	455	336	375	451	410	n.a.	-0.7
Islands in the Indian and Pacific Oceans[b/]	2,449	2,553	3,018	3,991	3,943	3,709	3.5
Others	111	122	143	122	135	n.a.	1.4
Developed market economy countries	2,300	4,300	6,863	10,878	10,015	10,390	11.1
United States	2,300	4,300	6,863	10,878	10,014	10,390[a/]	11.1
Socialist countries	989	2,300	3,889	5,188	5,736	n.a.	13.4
U.S.S.R.	989	1,927	3,575	5,168	5,655	5,887	13.3
Others	--	373	314	20	81	n.a.	n.a.

a/ Partly estimated.
b/ Christmas, Makatea, Nauru and Ocean Islands.
Source: United Nations, Conference on Trade and Development, International Action on Commodities in the Light of Recent Developments (TD/B/C.1/88/Rev. 1), 30 April 1971, Annex, table 6, p. 7.

Table 10. International Trade in Phosphate Rock in 1969 by Main Consuming Areas and Exporting Countries

(In thousands of tons, actual weight)

Exporting countries	Importing countries							
	Soc. coun.	EEC	U.K.	Other W. Eur. coun.	Japan	Other DME coun.	Dev. coun.	World
World............	7,675	11,233	1,648	4,511	2,970	5,745	3,208	36,990
Developing coun..	4,049	6,749	1,413	3,150	1,100	3,715	1,063	21,239
Algeria.........	299	39	2	20	--	--	--	360
Israel..........	294	268	143	116	33	--	16	870
Jordan..........	359	--	--	77	9	--	483	928
Morocco.........	2,036	3,838	1,056	2,514	494	49	277	10,264
Senegal.........	--	622	140	99	149	--	--	1,010
Togo............	--	1,306	--	--	158	--	--	1,464
Tunisia.........	754	665	44	321	--	--	71	1,855
UAR.............	307	--	--	3	--	--	100	410
Is. in the Ind. & Pac. Oceans a/	--	--	28	--	257	3,542	116	3,943
Others..........	--	11	--	--	--	124	--	135
Developed market economy coun....	--	3,319	106	545	1,869	2,030	2,144	10,015
United States...	--	3,319	106	545	1,868	2,030	2,144	10,014
Others..........	--	--	--	--	1	--	--	1
Socialist coun...	3,625	1,165	129	816	1	--	--	5,736
U.S.S.R.........	3,545	1,165	129	816	--	--	--	5,655
Others..........	80	--	--	--	1	--	--	81

a/ Christmas, Nauru and Ocean Islands.

Source: United Nations, Conference on Trade and Development, International Action on Commodities in the Light of Recent Developments (TD/B/C.1/88/Rev. 1), 30 April 1971, Annex, table 8, p. 9.

The unit values of phosphate rock exports from major exporting countries in 1955-69 are shown in table 11. These are averages on an actual weight basis, f.o.b. port of shipment. Since they do not include ocean and inland transport costs to destination, they are not a measure of comparative delivered costs. Most export prices, including U.S. prices, declined after 1967 in response to oversupply and severe competitive conditions in the world markets. The U.S. prices tended to be the lowest f.o.b., but when adjusted for differences in P_2O_5 content and in ocean transport costs to destination, for which no data are available, this advantage may disappear.

Table 11. Unit Values of Phosphate Rock Exports, 1955-69

Year	U.S.	U.S.S.R.	Morocco	Tunisia	Togo	Jordan	Senegal
	Dollars per ton actual weight						
1955..........	8.81	13.27	11.88	8.55	--	11.20	11.09
1960..........	8.70	16.90	11.08	8.92	--	11.46	13.50
1961..........	8.81	17.00	10.64	9.07	11.00	11.37	13.51
1962..........	9.02	17.01	10.59	8.75	10.76	11.38	12.61
1963..........	8.69	17.25	10.68	8.89	9.61	11.40	13.18
1964..........	9.16	17.56	11.34	8.95	9.85	10.55	13.30
1965..........	9.67	17.74	11.44	10.02	10.96	11.25	12.47
1966..........	10.22	17.25	11.48	10.41	15.78	11.60	12.84
1967..........	10.12	16.78	11.53	10.35	12.04	11.03	13.28
1968..........	9.54	16.38	10.64	9.67	10.42	10.18	12.88
1969..........	8.48	16.62	10.58	9.36	9.85	10.75	13.25
	Index: 1955=100						
1955..........	100.0	100.0	100.0	100.0	n.a.	100.0	100.0
1965..........	109.8	133.7	96.3	117.2	n.a.	100.4	112.4
1968..........	108.3	123.4	89.6	113.1	n.a.	96.3	116.1
1969..........	96.3	125.2	89.1	109.5	n.a.	96.0	119.5

Source: United Nations, Conference on Trade and Development, International Action on Commodities in the Light of Recent Developments (TD/D/C.1/88/Rev. 1), 30 April 1971, Annex, table 13, p. 14.

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IV. PHOSPHATE FERTILIZER MATERIALS

World trade in the phosphate nutrients required for fertilizers and other purposes may be in the form of phosphate rock or in the form of fertilizer materials, although the bulk of such trade is in the form of rock. As shown in table 12, however, in the past 10 years fertilizer materials in the form of ammonium phosphates and concentrated superphosphates have accounted for between 15 and 20 percent of total U.S. exports of phosphates. From 1959 to 1968, the P_2O_5 content of exported fertilizer materials increased from roughly 200,000 to nearly a million tons. Since 1968, there has been a decline to the 700,000 ton level. Most of the increase has been in ammonium phosphates. In addition to these materials, production and trade in phosphoric acid, used in the manufacture of ammonium phosphate, is increasing rapidly.

The form in which phosphorus is to be exported from the United States, i.e., as phosphate rock or as fertilizer materials, is a critical variable in the determination of future ocean transport and related port facility requirements. It is a variable that is governed by a variety of factors, most of which appear to be related to economic, institutional, and policy interests of the importing countries. These interests have emphasized the economic benefits in the form of increased employment and output, and reduced foreign exchange costs, of importing phosphate rock and processing it into fertilizer and other phosphorus materials, over the direct import of such materials themselves.

Governments have encouraged this by giving more favorable treatment to phosphate rock in their import

Table 12. United States Exports of Phosphate, P_2O_5 Content
(In thousands of short tons, unless otherwise stated)

Year	Phosphate rock	Fertilizer materials: Ammonium phosphates a/	Concentrated super-phosphates b/	Total	Percent of total P_2O_5 exported	Total P_2O_5
1948.....	353 c/	322	142	464	56.7	817
1949.....	457 c/	11	117	128	21.8	585
1950.....	611 c/	19	90	109	15.1	720
1951.....	582 c/	29	99	128	18.0	710
1952.....	487 c/	22	96	118	19.5	605
1953.....	715 c/	22	93	115	13.8	830
1954.....	842	23	145	168	16.6	1,010
1955.....	806	37	139	176	17.9	982
1956.....	981	39	182	221	18.3	1,202
1957.....	1,094	37	207	244	18.2	1,338
1958.....	993	23	188	211	17.5	1,204
1959.....	1,071	32	153	185	15.1	1,256
1960.....	1,445	49	154	203	12.3	1,648
1961.....	1,412	36	173	209	12.8	1,621
1962.....	1,421	56	206	262	15.5	1,683
1963.....	1,653	85	222	307	15.6	1,965
1964.....	2,055	167	262	429	17.2	2,484
1965.....	2,313	147	208	355	13.3	2,668
1966.....	2,803	355	252	607	19.8	3,410
1967.....	3,290	584	245	829	20.1	4,119
1968.....	3,917	584	382	966	19.8	4,883
1969.....	3,685	433	259	692	15.8	4,377
1970.....	3,528	470	233	703	16.6	4,231

continued--

Table 12. United States Exports of Phosphate, P_2O_5 Content continued--

a/ Ammonium phosphate multiplied by 46 percent to obtain P_2O_5 content.
b/ Superphosphate multiplied by 33 percent to obtain P_2O_5 content.
c/ Phosphate rock multiplied by 31 percent to obtain P_2O_5 content.

Source: 1948-67 -- U.S. Department of the Interior, The Phosphate Industry in the Southeastern United States and Its Relationship to World Mineral Fertilizer Demand, by John W. Sweeney and Robert N. Hasslacher, Bureau of Mines Information Circular 8459 (Washington, D.C.: Government Printing Office, 1970), p. 44. 1968-70 -- Calculated by RRNA from data in U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook 1969, and from Census Bureau foreign trade data.

tariff structures than to fertilizer and other phosphorus materials. Phosphate rock is admitted into most developed countries free of import duties or other restrictions. On the other hand, the EEC levies a duty of 4.8 percent ad valorem on imports of superphosphates and 13.2 percent on imports of phosphoric acid. However, imports from Tunisia, Morocco, and associated countries in Africa are admitted duty free. The United Kingdom levies an import duty of 11 percent on superphosphates and 6 1/2 percent on other phosphate fertilizers, but exempts imports from Commonwealth countries. Japan levies a duty of 13 percent on double or triple superphosphates, but admits other phosphate fertilizers free of duty. It levies a duty of 9 percent on phosphoric acid.1/

Since these duties are ad valorem and apply to the delivered price of a processed product, including the value added in the production process, their effective rate is somewhat higher than the nominal rate. According to one source, the effective rate of duty on triple superphosphates could be between 2 1/2 and 3 times the nominal rate, and the effective rate on phosphoric acid could be close to twice the nominal rate.2/

Relevant ocean transportation costs for phosphate rock and phosphorus fertilizer and other materials may also be an important consideration in the relative economic costs and benefits to the importing country. The most elementary consideration, of course, is the reduction in the proportion of waste materials transported in the movement of processed materials rather than of phosphate rock. Triple superphosphate or ammonium phosphate with a P_2O_5 content of 46 percent, when compared with a phosphate rock with 33 percent P_2O_5 content, permits an increase of nearly 40 percent in the volume of P_2O_5 transported per unit of bulk cargo.

1/ United Nations, Conference on Trade and Development, International Action on Commodities in the Light of Recent Developments (TD/B/C.1/88/Rev. 1), 30 April 1971, pp. 14 and 15.
2/ Ibid.

Assuming ocean transport characteristics were identical for both commodities, there should be a proportionate reduction in the ocean transport costs applicable to imports of processed materials. Thus, for example, an ocean transport rate of \$5 per ton of bulk material, whether phosphate rock or triple superphosphate, would be equivalent to \$15.15 per ton of P_2O_5 in phosphate rock and \$10.87 per ton of P_2O_5 in triple superphosphate. Even if such savings were attainable, the question of whether they are sufficient to offset the economic benefits to the importing country of importing the lower cost raw material over the higher cost processed material would need to be answered. Based on historical experience, it would appear that most developed countries of the free world have chosen to import the bulk of their phosphorus requirements in the form of phosphate rock.

This is corroborated by the market patterns of U.S. exports of phosphate fertilizer materials, of which only about one-third went to Canada, Western Europe, and Japan, and the balance to the less developed countries in Latin America and Asia.

However, changes in the technology of fertilizer production and usage may very well alter the economics of importing fertilizer materials over phosphate rock for the importing country. Among the more significant of these changes is the increased use of ammonium phosphates over concentrated superphosphates. Ammonium phosphates are manufactured from phosphoric acid. One hundred percent phosphoric acid is 72 percent P_2O_5, or approximately double that of phosphate rock. In a recent study of the phosphate requirements of the United Kingdom, it was estimated that by 1985, imports in thousands of tons would be as follows: phosphoric acid for ammonium phosphate manufacture, 900; phosphorus for fertilizers and other uses, 100; and phosphate rock for fertilizers and detergents, 700.

In 1967, United Kingdom imports of phosphate rock accounted for 500,000 tons P_2O_5 of total imports of 533,000 tons.1/

1/ A.J. Carleton, <u>Future Trends in the Importation and</u>

Despite the findings of the United Kingdom study (which did not include quantitative economic data or analysis of costs and benefits associated with the alternatives of importing phosphoric acid or phosphate rock), informed U.S. industry sources report that in both Europe and Japan there presently is a definite trend toward the displacement of small plants manufacturing superphosphates by large-volume phosphoric acid plants with access to deepwater port facilities. The process of plant concentration for the manufacture of phosphate fertilizer materials was being accompanied by corporate concentration as well. The resulting increase in the volumes of phosphate being purchased by a single entity and delivered to single locations for processing would facilitate the use of larger vessels in ocean transport than had been possible in the past.1/

A still further consideration affecting the form in which phosphorus materials will be exported from Florida in the future is the limitation by the Florida State Government on further expansion of phosphoric acid processing and other phosphate-processing facilities.2/

While it is clear from the above discussion that there are conflicting influences governing the relative U.S. export of phosphate rock on the one hand and phosphate fertilizer materials on the other, it would appear on balance that in the developed countries where volumes of consumption of phosphorus materials for fertilizer and other uses are very large, the net national economic benefit may continue to favor the import of phosphate rock.

In the developing countries, where volumes of consumption are much smaller, where capital required

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Handling of Phosphorus Materials, a summary of a survey carried out by Warren Spring Laboratory for the National Ports Council, Research and Technical Bulletin No. 7, United Kingdom, 1970.

1/ Based on discussions with officials of International Minerals Corporation, Skokie, Illinois, Jan. 28, 1972.

2/ Ibid.

for the construction of fertilizer plants is less readily available, and where a substantial portion of imports of phosphate fertilizer materials in recent years has been financed by United States and other foreign aid programs, it is expected that the bulk of phosphate imports will be in the form of fertilizer materials rather than phosphate rock.

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V. PROJECTIONS OF U.S. EXPORTS OF PHOSPHATE ROCK

The future volume of U.S. phosphate rock exports will largely be governed by the following variables:

1. The consumption of phosphorus materials for fertilizer and other uses in the rest of the world.

2. The competitive relationship in terms of cost and quality of U.S. phosphate rock delivered in foreign markets with phosphate rock from other world sources of supply.

3. The relative imports of phosphate rock on the one hand and processed phosphorus materials on the other.

4. The trade policies of the major importing countries.

Of these four variables, only foreign demand lends itself to projection by quantitative analytic techniques, although the available relevant data have serious shortcomings for that purpose. Of the other three, clearly the most critical is the element of competition from other world sources of supply, both existing and prospective. The North African countries have a quality advantage over Florida phosphate rock and a locational advantage in the markets of Western Europe, Africa and the Near East. In addition, they enjoy preferential tariff arrangements over the United States for the import of fertilizer materials in the EEC, the importance of which is enhanced by the recent admission of the United Kingdom and other new members.

Their reserves are the largest in the world, far superior to those of the United States and capable of supporting greatly increased levels of production. Reported plans to increase production include an expansion of capacity in Morocco to 18 million tons, in Tunisia to 8 million tons, and in the Spanish Sahara to 10 million tons, an aggregate increase in these countries over 1969 production of 21 million tons. In addition, there are projects completed or underway for the expansion of production in Israel and the United Arab Republic.[1/] Australia is reported to have large undeveloped reserves of phosphate rock, which would be advantageously located to the Japanese and Asian markets. Finally, there are the huge reserves and potential of the U.S.S.R., which is already supplying over 2 million tons of phosphate rock to Western Europe.

Institutional considerations are also of importance to an evaluation of future competition between U.S. and foreign suppliers. The producing enterprises in most of the leading foreign exporting countries are either state-owned or state-controlled entities. As such they are responsive to national policy interests aimed at exploiting the employment, income, and foreign exchange earning potential of their phosphate rock resources. While U.S. industry sources report no evidence of such practices at the present time, as instruments of national policy these entities may be regarded as having a potential for price cutting in the competitive market in order to maintain export volumes greater than that of private U.S. producers. In this connection, it should be noted that the percentage of total export earnings represented by exports of phosphate rock and fertilizers in 1969 was 25 percent for Morocco, 20 percent for Tunisia, 24 percent for Jordan, and 32 percent for Togo.

On the other hand there are offsetting institutional factors in the developed importing countries and

1/ United Nations, Trade and Development Conference, International Action on Commodities in the Light of Recent Developments (TD/B/C.1/88/Rev. 1), 30 April 1971, p. 21.

the United States. While Florida phosphate rock producers export a substantial share of their total output (38 percent in 1969), they are far less dependent upon export markets than are their major present and potential foreign competitors. Hence, they are in a position to engage in marginal cost pricing in the export markets if required to do so to remain competitive. This is reported to have been a factor in pricing practices in the last several years when there was a worldwide surplus of phosphate rock capacity accompanied by a drop in prices, including prices of Florida rock exports. Since there are no publicly available data on production costs in the United States or in foreign producing countries, it is impossible to assess the true economic cost relationship of the Florida phosphate producers and their potential for competing on a price and quality basis with foreign producers.

International trade policies of the major importing countries may have an influence on the future imports of Florida phosphate. The governments of Western Europe and Japan particularly may be reluctant to become excessively dependent upon phosphate imports from African, Arab, and Socialist countries. In the African and Arab countries, there is the threat of political instability and, perhaps even more importantly, the threat of the exercise of political influence over continuity of supplies and trading arrangements. The recent and current experience with the oil exporting countries of Africa and the Middle East is instructive on this point. Such influence may take the form of compulsory processing into fertilizer and other phosphorus materials in the rock-producing countries as a means of enhancing the economic benefits of the exploitation of their resources.

These considerations suggest that Japan and Western European countries could diversify sources of supply of phosphate rock and phosphate materials, including the provision for imports from U.S. sources, even though they may not be wholly competitive in economic terms.

However, the effects of such considerations of policy on imports are difficult to quantify. The

application of such a policy would not be uniform among all major importers, and would not imply the maintenance of existing shares for U.S. phosphate rock suppliers. In 1969 these shares were approximately 30 percent of EEC imports, 63 percent of Japanese imports, and 35 percent of imports by other non-Socialist developed countries (table 10).

Furthermore, even with the prospective growth in world demand for phosphate materials for fertilizer and other uses, given the apparent production and competitive potential of other world sources of supply and the possible development of processing facilities in the other producing countries, one does not have a firm basis for quantitative projections of the volume of U.S. exports of phosphate rock, and even less so of projecting significant growth in such exports.

The relevant variables in the projection of demand for phosphate materials are principally the demand for fertilizers; the phosphorus component of that demand; and the demand for phosphate material for other uses, such as in the manufacture of detergents.

With respect to the first variable, several considerations are relevant: (1) the growth rate in fertilizer consumption in developed countries, such as in Europe and Japan, is substantially lower than that of developing countries because of the already high consumption of fertilizer per population and cultivated land unit; (2) the demand for phosphatic fertilizers varies independently from total fertilizer demand both with time and with market area; and (3) there are no data on a worldwide basis on consumption of phosphate materials for nonfertilizer uses comparable to the data on consumption for fertilizer.

Only two studies available from other sources have projections to 1980 of foreign consumption of fertilizer nutrients, and of these only one has such projections in the geographic detail required for our

purposes.[1] It employs the following regional categories: North America, Western Europe, Eastern Europe, Oceania and Japan, Asia (excluding Japan and Communist Asia), Africa, Latin America, and Communist Asia.

All of these regions except Eastern Europe and Communist Asia were determined to be of sufficient importance as actual or potential markets for U.S. phosphate rock exports to warrant study and estimate of such exports for 1980 and 2000. However, since the TVA study combined Canada with the United States it was of no value for purposes of projecting exports to Canada.

The TVA study was prepared by the National Fertilizer Development Center, an institution which has the subject of world fertilizer supply and demand under continuous review, revising its projection every 2 years. The projections by region and fertilizer nutrient are "based on a combination of scientific and judgmental approaches," and were considered to be a reasonable basis for estimating U.S. phosphate exports in the present study.

Data from the TVA source on total consumption of fertilizer nutrients and of P_2O_5 for five regions for the years 1965, 1970, 1975, and 1980 are shown on tables 13 through 17. Also shown are the average annual growth rates for total fertilizer and P_2O_5 consumption for each of the 5-year periods, and the proportion of total fertilizer nutrient consumption represented by P_2O_5 fertilizer. This was found to differ substantially among the regions.

From these data estimates were developed of P_2O_5 consumption for nonfertilizer purposes through the use

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1/ Tennessee Valley Authority, National Fertilizer Development Center, Estimated World Fertilizer Production Capacity as Related to Future Needs, 1970 to 1975, by E.A. Harre et al., Bulletin Y-7 (Muscle Shoals, Alabama: TVA, June 1970).

Table 13. Western Europe - Consumption and Imports of Phosphate Rock and Fertilizer Materials 1965, 1970, and Estimated 1975, 1980 and 2000

(In millions of metric tons)

Consumption and imports	1965	1970	1975	1980	2000
Consumption					
Total fertilizer consumption...	12.51	15.46	17.78	20.09	26.96
Annual growth rate...........	--	4.3	2.9	2.5	1.5
P_2O_5 consumption..............	4.33	5.06	5.63	6.19	7.55
Percent of total fertilizer...	34.6	32.7	31.7	30.8	28.0
Annual growth rate..........	--	3.2	2.2	1.9	1.0
Other P_2O_5 consumption.........	1.44	1.87	2.30	2.78	4.07
Percent of total.............	25.0	27.0	29.0	31.0	35.0
Total P_2O_5 consumption.........	5.77	6.93	7.93	8.97	11.62
P_2O_5 imports					
Phosphate rock[a/]:					
United States................	n.a.	1.32	1.47	1.64	2.00
Total........................	4.82	5.94	6.68	7.47	9.12
Fertilizer materials..........	.76	1.07	1.25	1.50	2.50
Total P_2O_5 imports............	5.58	7.01	7.93	8.97	11.62

a/ Converted to P_2O_5 at .33 per ton of phosphate rock.

Source: Total fertilizer and P_2O_5 consumption -- Tennessee Valley Authority, National Fertilizer Development Center, Estimated World Fertilizer Production Capacity as Related to Future Needs, 1970 to 1975, by E.A. Harre et al., Bulletin Y-7 (Muscle Shoals, Alabama: TVA, June 1970), p. 24. Total

continued--

Table 13. Western Europe - Consumption and Imports of Phosphate Rock and Fertilizer Materials 1965, 1970, and Estimated 1975, 1980 and 2000

phosphate rock imports, 1965 -- United Nations, Conference on Trade and Development, International Action on Commodities in the Light of Recent Developments (TD/B/C.1/88/Rev. 1), 30 April 1971. Phosphate rock imports, 1970 -- International Superphosphate & Compound Manufacturers' Association Limited, Phosphate Rock Statistics 1970, London, 1970, table 4. Fertilizer materials, 1965 and 1970 -- Food and Agriculture Organization, Annual Fertilizer Review, 1970. All others -- estimated by RRNA.

Table 14. Latin America - Consumption and Imports of Phosphate Rock and Fertilizer Materials 1965, 1970, and Estimated 1975, 1980 and 2000

(In millions of metric tons)

Consumption and imports	1965	1970	1975	1980	2000
Consumption					
Total fertilizer consumption...	1.47	2.91	5.16	7.41	15.34
Annual growth rate...........	--	14.6	18.7	7.5	3.7
P_2O_5 consumption...............	.45	.94	1.70	2.45	5.37
Percent of total fertilizer...	30.6	32.3	32.9	33.1	35.0
Annual growth rate..........	--	15.9	12.6	7.6	4.0
Other P_2O_5 consumption.........	.05	.10	.19	.27	.60
Percent of total.............	10.0	10.0	10.0	10.0	10.0
Total P_2O_5 consumption.........	.50	1.04	1.89	2.72	5.97
P_2O_5 imports					
Phosphate rock[a]:					
United States................	n.a.	.44	.75	1.00	2.00
Total........................	n.a.	.50	1.13	1.63	3.60
Fertilizer materials..........	.16	.32	.76	1.09	2.37
Total P_2O_5 imports............	n.a.	.82	1.89	2.72	5.97

a/ Converted to P_2O_5 at .33 per ton of phosphate rock.

Source: See table 13.

Table 15. Oceania and Japan - Consumption and Imports of Phosphate Rock and Fertilizer Materials 1965, 1970, and Estimated 1975, 1980 and 2000

(In millions of metric tons)

Consumption and imports	1965	1970	1975	1980	2000
Consumption					
Total fertilizer consumption...	3.25	4.02	4.86	5.70	9.30
Annual growth rate...........	--	4.3	3.9	3.2	2.5
P_2O_5 consumption..............	1.72	2.02	2.58	3.13	4.65
Percent of total fertilizer...	52.9	50.2	53.1	54.9	50.0
Annual growth rate..........	--	3.3	5.0	3.9	2.0
Other P_2O_5 consumption.........	.51	.67	.95	1.28	2.50
Percent of total.............	23.0	25.0	27.0	29.0	35.0
Total P_2O_5 consumption.........	2.23	2.69	3.53	4.41	7.15
P_2O_5 imports					
Phosphate rock[a/]:					
United States................	n.a.	.62	.75	.90	1.40
Total........................	2.00	2.13	2.93	3.61	5.85
Fertilizers..................	.14	.46	.60	.80	1.30
Total P_2O_5 imports............	2.24	2.59	3.53	4.41	7.15

a/ Converted to P_2O_5 at .33 per ton of phosphate rock.

Source: See table 13.

Table 16. Asia (Excluding Japan and Communist Asia) - Consumption and Imports of Phosphate Rock and Fertilizer Materials 1965, 1970, and Estimated 1975, 1980 and 2000

(In millions of metric tons)

Consumption and imports	1965	1970	1975	1980	2000
Consumption					
Total fertilizer consumption...	2.09	5.17	9.15	13.13	25.63
Annual growth rate...........	--	19.9	12.1	7.5	3.4
P_2O_5 consumption..............	.50	1.19	2.35	3.51	7.69
Percent of total fertilizer...	23.9	23.0	25.7	26.7	30.0
Annual growth rate..........	--	18.9	14.3	8.4	4.0
Other P_2O_5 consumption........	.05	.13	.26	.39	.85
Percent of total.............	10.0	10.0	10.0	10.0	10.0
Total P_2O_5 consumption........	.55	1.32	2.61	3.90	8.54
P_2O_5 imports					
Phosphate rock[a/]:					
United States................	n.a.	.38	.70	1.00	1.50
Total........................	n.a.	.58	1.39	2.07	4.54
Fertilizer materials..........	.30	.56	1.22	1.83	4.00
Total P_2O_5 imports............	n.a.	1.14	2.61	3.90	8.54

a/ Converted to P_2O_5 at .33 per ton of phosphate rock.

Source: See table 13.

Table 17. Africa - Consumption and Imports of Phosphate Rock and Fertilizer Materials 1965, 1970, and Estimated 1975, 1980 and 2000

(In millions of metric tons)

Consumption and imports	1965	1970	1975	1980	2000
Consumption					
Total fertilizer consumption...	.92	1.63	2.55	3.48	6.93
Annual growth rate............	--	12.1	9.4	6.4	3.5
P_2O_5 consumption..............	.25	.56	.75	.95	2.08
Percent of total fertilizer...	27.2	34.4	29.4	27.3	30.0
Annual growth rate...........	--	17.5	6.0	4.8	4.0
Other P_2O_5 consumption.........	.03	.06	.08	.11	.23
Percent of total.............	10.0	10.0	10.0	10.0	10.0
Total P_2O_5 consumption.........	.28	.62	.83	1.06	2.31
P_2O_5 imports					
Phosphate rock[a/]:					
United States.................	--	--	--	--	--
Total.......................	--	--	--	--	--
Fertilizer materials..........	0.7	.10	--	--	--
Total P_2O_5 imports............	0.7	.10	--	--	--

a/ Converted to P_2O_5 at .33 per ton of phosphate rock.

Source: Total fertilizer and P_2O_5 consumption -- Tennessee Valley Authority, National Fertilizer Development Center, Estimated World Fertilizer Production Capacity as Related to Future Needs, 1970 to 1975, by E.A. Harre et al., Bulletin Y-7 (Muscle Shoals, Alabama: TVA, June 1970), p. 29. All others -- estimated by RRNA.

of appropriate assumptions as to the ratio which such consumption bore to total P_2O_5 consumption. For the developed regions, i.e., Western Europe and Oceania and Japan, it was assumed that this ratio was slightly below that of the United States. For 1969 the U.S. ratio was estimated at 27 percent, after adjustments of the USDA and Bureau of Mines data for losses of P_2O_5 in the processing of phosphate rock. It was also assumed that future growth of consumption of P_2O_5 for nonfertilizer purposes in developed countries would be more rapid than for fertilizer purposes.

For the developing regions, i.e., Latin America and Asia (other than Japan and Communist Asia), an arbitrary assumption was made that nonfertilizer use of P_2O_5 was 10 percent of total P_2O_5 consumption, and that the growth rate of consumption for both categories of end use would be the same.

Consumption was estimated for the year 2000 for each of the regions by employing appropriate assumptions as to average annual growth rates during the 1980-2000 period for P_2O_5 fertilizer consumption, and the ratio of P_2O_5 to total nutrient consumption.

For the base years 1965 and 1970, data were tabulated for each of the regions on total imports of phosphate rock, imports from the United States, and imports of phosphate fertilizers. These are expressed in tables 13 through 17 in P_2O_5 equivalent. The aggregates of these imports were found to correspond closely with the estimates of consumption for the base years. From these data and the projections of total P_2O_5 consumption, estimates were made for 1975, 1980 and 2000 of imports of P_2O_5 in the form of fertilizer materials and of phosphate rock, and a further estimate was made of the phosphate rock imports from the United States.

For the projection years, it was assumed that the proportionate imports of phosphate rock and fertilizers would be roughly the same as in the base years. Assumptions as to the share of the United States in the phosphate rock market varied with each region, reflecting

judgments as to relative competitive relationships with other world sources of supply in each region and the influence of the institutional factors discussed earlier. In Western Europe, it was assumed that the U. S. share would be fairly stable. In the other regions, it was assumed to decline, but in the year 2000 it was assumed to still account for 56 percent in Latin America, 24 percent in Oceania and Japan, and 33 percent in other Asia, excluding Japan and Communist Asia.

U.S. exports to Oceania and Japan were assumed to go entirely to the latter country, reflecting the trend in recent years for Oceania to import phosphate rock from Pacific Island sources.

From these estimates by region, more detailed estimates by the foreign coastal zone areas employed in the Deepwater Port Study were prepared and are shown in table 18, compared with actual data for 1969. Total U.S. waterborne phosphate rock exports, including shipments to Canada, are estimated at 17.9 million and 26.5 million tons actual weight for 1980 and 2000, respectively. Of these totals, shipments from the gulf coast ports of Tampa and Boca Grande for 1980 and 2000 are estimated at 15.9 million and 22.7 million tons, respectively.

It is assumed that Africa, as a whole, will be self-sufficient in phosphate rock. It is further assumed that Communist Europe and Communist Asia will not import phosphate rock from the United States, although it should be pointed out that Mainland China imported 1.2 million metric tons of phosphate rock in 1970, mostly from Morocco.

Comparison with Other Studies

Table 19 summarizes projections of fertilizer consumption and U.S. exports of phosphate rock from 10 different source studies, which are identified in the list of projection sources attached to the table. Comparisons of the projections in the present study with those of the other studies can be made only for U.S.

Table 18. U.S. Waterborne Exports of Phosphate Rock by Foreign Coastal Zone 1969 and Estimated 1980 and 2000

(In millions of short tons)

Country and region	Zone	1969	1980	2000
Canada	1	1.1	1.7	2.0
Latin America and Caribbean	2	0.7	2.0	3.5
	3	0.1	0.4	.8
	4	0.3	1.2	2.8
Northwest Europe	5	2.9	3.8	4.7
Southwest Europe	6	1.5	2.0	2.4
Other Mediterranean	7	a/	--	--
Eastern Europe	8	--	--	--
Africa-Atlantic and Indian Ocean	9	a/	--	--
Middle East	10	a/	--	--
South Asia	11	0.3	1.8	2.6
Southeast Asia	12	0.9	1.8	2.7
Oceania	13	0.1	--	--
Communist Asia	14	--	--	--
Japan	15	2.1	3.2	5.0
Total		10.0	17.9	26.5
U.S. port of shipment				
Beaufort, N.C.	--	0.3	0.5	0.8
Jacksonville	--	0.8	1.5	3.0
Tampa-Boca Grande	--	8.9	15.9	22.7

a/ Less than 50,000 tons.

Table 19. Summary of Fertilizer and Phosphate Projections

(In millions of short tons)

Projection sources[a]	1975	1980	1985	1990	1995	2000
World consumption						
Total plant nutrients:						
TVA (6)..............	98.1	126.7	--	--	--	--
Bureau of Mines (7) (median estimate)....	--	--	113.0	--	--	204.0
Phosphate fertilizer (P_2O_5 content):						
TVA (6)..............	27.6	35.3	--	--	--	--
Bureau of Mines (7) (median estimate)...	--	--	35.0	--	--	63.0
Bureau of Mines (8) (median estimate)[b,c]	--	--	--	--	--	135.7
U.S. consumption						
Total plant nutrients:						
Bureau of Mines (3) (median estimate)...	--	30.8	--	--	--	--
USDA (10) (median estimate)...........	--	28.3	--	--	--	--
Coleman (9)..........	--	26.6	--	--	--	--
Phosphate fertilizer (P_2O_5 content):						
Bureau of Mines (8)[b,c] (median estimate)	--	--	--	--	--	28.0
USDA (10) (median estimate)...........	--	6.9	--	--	--	--
Bureau of Mines (3) (median estimate)[b].	--	12.1	--	--	--	--
Coleman (9)..........	--	7.6	--	--	--	--
U.S. exports of phosphate rock						
Booz-Allen (1) (median estimate)........	11.6	15.1	18.8	23.2	28.2	--
Stanford Research (2).	15.6	--	--	--	56.0	--
Stanford Research (4)[d]	--	14.0	--	23.0	--	37.0

continued--

Table 19. Summary of Fertilizer and Phosphate Projections continued--

(In millions of short tons)

Projection sources[a]	1975	1980	1985	1990	1995	2000
Bureau of Mines (7) (median estimate):						
Total U.S.	--	--	17.0	--	--	27.0
Southeastern U.S.	--	--	15.0	--	--	24.0
Corps of Engineers (5)[e]	12.2	14.2	--	1[illegible].3	--	20.0
Bureau of Mines (3)[f].	--	18.5	--	--	--	--

a/ Numbers in parentheses in this column refer to items listed under Projection Sources below.
b/ Includes nonfertilizer uses.
c/ Converted to P_2O_5 equivalent from phosphorus.
d/ Export and domestic movement through the Port of Tampa.
e/ Exports through the Port of Tampa.
f/ Converted from P_2O_5 at .325 per ton of phosphate rock.

Projection Sources

1. Booz-Allen Applied Research, Inc., Forecast of U.S. Oceanborne Foreign Trade in Bulk Commodities, March 1969. (Projections of U.S. phosphate rock exports 1975, 1980, 1985, 1990, and 1995.)

2. Stanford Research Institute, Projections of Principal U.S. Dry Bulk Commodity Seaborne Imports and Exports for 1975 and 1995, February 1969. (Projections of U.S. phosphate rock exports, 1975 and 1995.)

3. U.S. Department of the Interior, A Statistical Analysis of U.S. Demand for Phosphate Rock, Potash, and Nitrogen, by Olmon Hee, Bureau of Mines Information Circular 8418 (Washington, D.C.: Government Printing Office, 1969). (Projections to 1980 of U.S. production, consumption, and exports of phosphate rock and other fertilizer materials.)

continued--

Table 19. Summary of Fertilizer and Phosphate Projections continued--

4. Stanford Research Institute, Preliminary Evaluation of the Future Requirements for Marine Terminals in Tampa Bay (Tampa, Florida: Tampa Port Authority, 1968). (Projections of phosphate rock traffic through Tampa Harbor for 1980, 1990, and 2000.)

5. U.S. Army Corps of Engineers, Survey Report on Tampa Harbor, Florida, September 1969. (Projections of world phosphate rock production and exports from Tampa Harbor for 1975.)

6. Tennessee Valley Authority, National Fertilizer Development Center, Estimated World Fertilizer Production Capacity as Related to Future Needs, 1970 to 1975, by E.A. Harre et al., Bulletin Y-7 (Muscle Shoals, Alabama: TVA, June 1970). (Projections of world P_2O_5 and other fertilizer production and consumption by region and continent, 1975 and 1980.)

7. U.S. Department of the Interior, The Phosphate Industry in the Southeastern United States and Its Relationship to World Mineral Fertilizer Demand, by John W. Sweeney and Robert N. Hasslacher, Bureau of Mines Information Circular 8459 (Washington, D.C.: Government Printing Office, 1970). (Projections for 1985 and 2000 of world fertilizer demand and U.S. exports of phosphate rock.)

8. Richard W. Lewis, "Phosphorus," in U.S. Department of the Interior, Minerals Facts and Problems, 1970 ed., Bureau of Mines Bulletin 650 (Washington, D.C.: Government Printing Office, 1970), pp. 1139-55. (Projections for 2000 of U.S. and rest of world phosphorus demand.)

9. Russell Coleman, "The Outlook for Fertilizer," in Chemical Engineering Progress, vol. 64, no. 7, July 1969, pp. 68-71. (U.S. consumption of P_2O_5 and other fertilizers, 1980.)

10. U.S. Department of Agriculture, Fertilizer Use in the United States, by D.B. Ibach, Agricultural Economic Report, May 1966. (U.S. consumption of P_2O_5 and other fertilizer, 1980.)

exports for the years 1980 and 2000. Our estimates of waterborne exports of 17.9 million tons in 1980 compares with the median estimate by Booz-Allen of 15.1 million, and a Bureau of Mines estimate of total exports of 18.5 million tons. Our estimate of 15.9 million tons to be shipped from Tampa and Boca Grande compares with a Stanford Research estimate of 14.0 million and a Corps of Engineers estimate of 14.2 million for the port of Tampa only.

For the year 2000, our estimate of 26.5 million tons of total waterborne exports compares with estimates for 1995 by Booz-Allen of 28.2 million tons and by Stanford Research in a study for the Maritime Administration of 56.0 million tons. In a later study for the Tampa Port Authority, Stanford Research estimated exports through the port of Tampa at 37.0 million tons in 2000. In a 1969 survey report, the Corps of Engineers estimated shipments through the port of Tampa in 2000 at 20 million tons.

ANNEX A-8. ANALYSIS OF MAINLAND CHINA'S PROSPECTIVE GRAIN IMPORT REQUIREMENTS AND COKING COAL EXPORT POTENTIAL

CONTENTS

INTRODUCTION

Because Mainland China (The People's Republic of China) is the world's most populous nation and possesses extensive natural resources, it was considered important to give some attention in the U.S. Deepwater Port Study to its potential as a market for and as a source of bulk raw materials. This attention appears to be particularly important in view of developing relations between the Governments of the People's Republic of China and the United States and other Western and Asiatic countries.

Of the six bulk commodities included in the Deepwater Port Study, it was concluded that the most relevant to possible future Chinese trade development would be the import of food and feed grains, which Mainland China has been importing from the free world for several years, and the export of coal, of which Mainland China has extensive resources and of which it is one of the world's largest producers.

As an importer of grains, Mainland China would be a potential market for U.S. grain exports. As an exporter of coal, it would be a potential competitor in foreign markets, particularly in Japan, of U.S. coal exports. This annex develops basic background data on Chinese agricultural resources, food requirements, and coal resources which may be useful in appraising the long-range future prospects of that nation as a grain importer and a coal exporter.

Although Mainland China has considerable potential both as a grain importer and as a coal exporter,

uncertainties with respect to future Chinese policies and economic development precluded quantitative forecasts for 1980 and 2000. Hence, in relation to the projections of U.S. exports in the basic commodity studies in Annexes A-5 and A-6, exports of grains to Mainland China from the United States would be additive and exports of coal from Mainland China to Japan would be negative.

I. GRAIN IMPORT PROSPECTS OF MAINLAND CHINA

Introduction

With a population estimated at 800 to 850 million and an average per capita income that is among the lowest in the world, the food consumption pattern in Mainland China is similar to that in other countries with similar per capita income levels; i.e., the diet is made up almost entirely of cereal grains, and there is very little meat consumption or the feeding of grains to livestock and poultry. (See Annex A-6, "U.S. Exports of Grains, Soybeans and Meal.") The possibility of significant volumes of imports of grains into Mainland China in the future does not rest on any predicted changes in dietary patterns resulting from increases in per capita income (for instance, the subs ι ιtion of meat consumption for grain consumption, anu related growth in the demand for feed grains for livestock). It rests rather on uncertainty about Mainland China's ability to ma'ntain a rate of growth in food grain production comp able to its population growth.

Similar uncertainty exists with respect to other major less developed countries, such as India and Pakistan, whose combined population in these countries ranks second to Mainland China. However, the success of the so-called Green Revolution in recent years has resulted in a growth in agricultural output in excess of population growth, and offers some hope of long-range self-sufficiency in basic foodstuffs. In Mainland China, on the other hand, the uncertainty is somewhat greater, partly because of differences in basic agricultural resources relative to other countries, partly because of the negative effects on agricultural production of

experimentation in political and economic policy in the rural agricultural areas, and partly because of uncertainty with respect to future policies.

Uncertainty also arises from the inadequacies and unreliability of basic agricultural data required for analytic purposes. These are familiar problems in all less developed countries, but are somewhat aggravated in the case of China by the sheer massiveness of the country, by political upheavals, and by the instability which inevitably accompanies such social and economic experimentation as the so-called "Great Leap Forward" and "The Cultural Revolution."

Mainland China, like most other developing countries, depends heavily upon the performance of the agricultural sector of its economy. At the time the Communists assumed control, agriculture's share of Mainland China's national income was roughly 50 percent.1/ Since that time its share is estimated to have decreased to somewhere between 33 percent and 50 percent as a result of the increased emphasis placed on industrial output.2/ This compares with the share of agriculture, forestry, and fisheries in national income in the United States of 7.3 percent in 1950 and 3.1 percent in 1970. Agriculture commands 80 to 85 percent of the total labor force, while its products account for approximately 60 to 70 percent of the value of total exports.3/ As the agricultural sector virtually dominates the total economy in terms of its relative share of aggregate output and available supplies of labor, Mainland China's

1/ Alexander Eckstein, "The Economic Heritage," in Economic Trends in Communist China, ed. Alexander Eckstein, Walter Galenson and Ta-Chung Liu (Chicago: Aldine Publishing Company, 1968), p. 80.
2/ Marion R. Larsen, "China's Agriculture Under Communism," in U.S. Congress, Joint Economic Committee, An Economic Profile of Mainland China, 90th Cong., 1st Sess. (Washington, D.C.: Government Printing Office, 1967), Vol. I, p. 205.
3/ Ibid., p. 204.

social and economic conditions in terms of food consumption, foreign and domestic trade, industrial output and gross national product are critically linked to the volume of national crop production.

Cultivated areas, which are concentrated in the eastern region of the country, occupy approximately 12 percent of Mainland China's total land area and are divided basically along an east-to-west line which roughly follows the 34th parallel.1/ North of the parallel, spring and winter wheat crops predominate, while the southern areas are famed for their intensively cultivated rice crops. An estimated 40 percent of the total cultivated areas are double-cropped, most of this in the southernmost rice regions.2/ Traditional crops include corn, potatoes, oats, sorghum, peas, beans, oilseeds, millet, kaoliang, barley, sweet potatoes, sugarcane, sugar beets, rye and tobacco. Rice or wheat, however, is the staple diet of the Chinese. In the northern wheat regions, rice is considered a luxury food, while wheat consumption in the southern rice areas is negligible.

Additional land potentially suitable for farming is in scarce supply in Mainland China. Insufficient rainfall, rugged terrain, limited growing seasons, or poor soils severely limit both the amount of reclaimable land and its marginal productivity in Mainland China's western and far northern regions3/ with the exception of the Sinkiang oases. Consequently, government efforts to increase agricultural output have been directed in particular toward increasing yields per acre rather than toward increasing the amount of total arable land. In this manner, the government hopes to be able to return Mainland China to a state of agricultural self-sufficiency -- a state it has not enjoyed for nearly a dozen years.

1/ United Nations, Food and Agriculture Organization, The State of Food and Agriculture, 1970 (Rome, FAO, 1970), p. 96.
2/ Communist China Map Folio (Washington, D.C.: Central Intelligence Agency, 1967) page on Agriculture.
3/ Ibid.

This limitation of potential agricultural land in Mainland China is of special significance when compared with other major countries. As shown in table 1, the estimated amount of arable land per person engaged in agriculture in Mainland China is 0.16 hectares (0.4 acres), approximately one-quarter that of India and Thailand and about one-half that of Pakistan. With a population over four times that of the United States. Mainland China has approximately one-third less cultivated land. On a per capita basis, Mainland China has 0.35 acres of cultivated land compared with 1.9 acres in the United States. However, this deficiency in land devoted to agriculture is offset partly by the practice of double cropping which, it is estimated, effectively increases the cultivated land area by approximately 50 percent.1/

Despite these resource limitations, Mainland China has not traditionally been a net food importer. However, for more than a decade, it has been importing substantial quantities of foreign wheat. Since December 1960, when the first contract was signed for 305,000 tons of Australian wheat, Chinese agriculture has found itself incapable of producing grain in sufficient quantities to fill the demands of its expanding population2/ (table 2).

The Great Leap Forward

Among the conditions which initially propelled Mainland China, traditionally a net food-grain exporter, into the world wheat market in late 1960 was the Great Leap Forward, China's first crash program of economic development that was officially inaugurated in January

1/ Marion R. Lawsen, "China's Agriculture Under Communism," in U.S. Congress, Joint Economic Committee, An Economic Profile of Mainland China, Vol. I, pp. 207 and 208.
2/ U.S. Department of Agriculture, The Agricultural Situation in Communist Areas, Review of 1970 and Outlook for 1971, Economic Research Service Foreign Bulletin 314, Washington, D.C., 1971, p. 35.

Table 1. Comparison of Selected Agricultural Data for Various Less Developed Far Eastern Countries

Country	Total population in agriculture	Share of agriculture in total GDP	Share of agricultural products in value of total export trade	Arable land per person in agriculture	Fertilizer consumption per ha. of arable land
	------------ percent		-----------------	--- ha. --	--- kil.---
India					
1950......	70[a]	51	--	0.53	--
1960......	73[b]	50	44	0.51	2
1965......	70	46	38	0.48	5
1967......	--	52	41	--	11
Pakistan					
1950......	--	58	--	--	--
1960......	75[b]	53	--	0.42	--
1965......	74	47	62	0.34	5
1967......	--	47	49	--	11
Thailand					
1950......	66	--	--	0.39	--
1960......	82	39	89	0.13	2
1965......	78	32	84	0.48	3
1967......	--	31	80	--	9
Mainland China					
1952......	--	50	--	--	.65[c]
1957......	--	--	78[d]	--	2.63[c]
1962......	--	--	63[e]	--	4.74[c]
1966......	80-85	30-50	61[f]	0.16[g]	13.81[c]

continued--

Table 1. Comparison of Selected Agricultural Data for Various Less Developed Far Eastern Countries continued--

a/ 1951.
b/ 1961.
c/ Converted to kg./hectare from estimates in An Economic Profile of Mainland China, Vol. I, p. 246.
d/ 1957 data not available. Calculation based on share of agricultural products and textiles in total 1959 export trade.
e/ Calculation based on share of agricultural products and textiles in total export trade.
f/ 1966 data not available. Calculation based on share of agricultural products and textiles in total 1965 export trade.
g/ Computed from agricultural population as 80-85 percent of total and .35 acres of arable land per capita of total population. Converted to hectares from estimates in An Economic Profile of Mainland China, Vol. I, pp. XII and 205.

Source: Data on India, Pakistan, and Thailand -- United Nations, Food and Agriculture Organization, The State of Food and Agriculture 1970 (Rome, FAO, 1970), p. 238. Data on Mainland China -- U.S. Congress, Joint Economic Committee, An Economic Profile of Mainland China, 90th Cong., 1st sess. (Washington, D.C.: Government Printing Office, 1967), Vol. I, pp. XII, 204, 205, 246, and Vol. II, p. 586.

Table 2. Mainland China's Imports of Wheat by Country of Origin, 1960-61 to 1970-71

(In millions of tons)

Year	Australia	Canada	Argentina	France	Other	Total
1960-61......	1.16	.78			.01	1.95
1961-62......	1.93	1.97	.09	0.20	.54	4.73
1962-63......	2.07	1.68	.10	0.87	.17	4.89
1963-64......	2.54	1.00	.99	0.22	.33	5.08
1964-65......	2.25	1.76	.60			4.61
1965-66......	1.97	2.05	2.22	.04	.03	6.31
1966-67......	2.16	2.46	.32	.07		5.01
1967-68......	2.42	1.37		.60		4.39
1968-69......	1.18	2.10				3.28
1969-70......	2.37	1.83		.58		4.78
1970-71a/....	1.09	2.52		.25		3.86

a/ Preliminary.

Source: U.S. Department of Agriculture, The Agricultural Situation in Communist Areas, Review of 1970 and Outlook for 1971, Economic Research Service Foreign Bulletin 314, Washington, D.C., 1971, p. 34.

1958. The brainchild of Chairman Mao Tse-Tung, the Great Leap Forward found its essence in Mao's reification of szu-hsiang -- a Chinese term which roughly corresponds to ideological motivation or the link between thought and action. The policies and goals of the Great Leap Forward represented an extension of Mao's belief that complex economic and social development problems could be overcome simply by the mass application of "correct" Marxist-Leninist thought. Despite grossly insufficient capital resources and ill-prepared planning, the program was quickly adopted.

On the one hand, output goals in nearly every sector of the economy were doubled, while daily productivity was expected to increase at an astronomical rate. On the other hand, nonpolitical incentives were conspicuously absent. The ultimate dysfunction of the Great Leap Forward resulted from its inability to effectively bridge the gap between the regime's idealistic goals and its lack of pragmatic policy planning. That gap caused the Great Leap Forward to stagnate and ultimately to be counterproductive to its intended social and economic ends.

The agricultural sector was particularly hard-hit by the failure of the Great Leap Forward. Prior to the implementation of the Leap's programs, the system of agricultural collectivization which had been in effect since 1956 made allowance for a network of private family vegetable plots and hog pens. The vegetables could be sold for cash in the cities, while the government purchased the hogs from the peasants at a price which provided the peasant with a small profit margin for his efforts. The hogs were subsequently slaughtered and exported, providing Mainland China with a substantial portion of its foreign exchange revenues.

By 1958, however, the program of collectivization was radically altered by the regime when it believed that the time was right for the institution of a full-scale program of agricultural communization. Production units were centralized at the township level, each unit being stratified in three layers: the commune, the "organization district" or large production unit, and

the production brigade or team.1/ Private plots were outlawed. The allegedly "capitalistic" method of food distribution according to labor input was superseded by the practice of distribution according to inputs of labor time and relative need.2/

As a consequence of these and other unsuccessful programs, such as the "backyard blast furnace" fiasco, agricultural productivity was dealt a crushing blow. Rather than doubling, 1959 grain output was reduced so precipitously that it was not until 1964 that harvests approached the level they had attained in 1957.

Grain output figures referred to are those of O.L. Dawson, appearing in table 3, and of the Department of Agriculture, appearing in table 4, the latter providing production data for 1966 to 1970, which are not included in table 3. The O.L. Dawson estimates, going back to 1949, are an interesting contrast with the official estimates of the Chinese Government. For the period 1949-55, the official estimates are below those of Mr. Dawson, undoubtedly due to shortcomings in the statistical reporting process. For 1957 and 1958, there is very little difference between the two sets of estimates. But in 1959 and 1960, the first 2 years of the Great Leap Forward the official estimates show grain production rising from 185 million to 270 million metric tons. Mr. Dawson, on the other hand, estimates a decline of 15 million tons in the same period. From 1960 onward, the differences between the two sets of estimates are not quantitatively significant.

Along with these developments came 3 years of unfavorable weather. From 1959 to 1961, Chinese agricultural production dropped to a crisis level (table 3). The combination of substandard harvests, general inefficiency, dissatisfaction with the poorly administered

1/ Kenneth R. Walker, "Organization of Agricultural Production," in Economic Trends in Communist China, ed. Alexander Eckstein, Walter Galenson and Ta-Chung Liu, p. 443.
2/ Ibid., p. 443.

Table 3. Estimates of Chinese Grain Output, 1949-65

Year	Crop weather	Population (millions)	Official estimate[a] (mil. of tons)	O.L. Dawson's estimate[b]	
				Output (mil. of tons)	Per capita (kg.)
Pre-1949 peak.....	--	530	138.7	170	320
1949..............	Poor	545	108.1	150	275
1952..............	Good	575	154.4	170	296
1953..............	Average	588	156.9	166	284
1954..............	Poor	602	160.5	170	282
1955..............	Good	615	174.8	185	301
1956..............	Poor	630	182.5	175-180	278-286
1957..............	Average	645	185.0	185	287
1958..............	Good	659	250.0	204	310
1959..............	Average	669	270.0	170	254
1960..............	Poor	676	150.0	160	237
1961..............	Poor	680	162.0	170	250
1962..............	Good	687	174.0	180	262
1963..............	Average	697	183.0	185	265
1964..............	Good	712	200.0	195	274
1965............	Average	728	200.0	193-200	265-275
1970 (plan).......	--	810	243.0	--	--

a/ The 1958 and 1959 official estimates are not taken seriously. Since 1960 Peking has not published grain output estimates in the domestic press, but Peking officials have discussed the estimates with foreigners. Mao Tse-Tung told Viscount Montgomery in September 1961 that the 1960 output had been 150 million tons, and that the preliminary estimate for 1961 was 160 million tons.

continued--

Table 3. Estimates of Chinese Grain Output, 1949-65
continued--

In April 1963 Chou En-lai told a Dawn (Pakistan) reporter that the grain output increase in both 1961 and 1962 had exceeded 10 million tons, and an emigrant source mentioned a 1962 estimate of 174 million tons. At the end of 1964, Edgar Snow was given an estimate for 1964 of 200 million tons and a percentage increase which placed the 1963 estimate at 183 million tons. In 1966 several Peking officials stated that the 1965 output had been 200 million tons, remaining at the 1964 level. The 1970 plan target is estimated on the basis of a stated intention to reach satisfactory levels of per capita grain output, which is assumed to mean the conventional standard of 300 kilograms per capita for an expected population of 810 million.

b/ Estimates of the former U.S. agricultural attache in China.

Source: Edwin F. Jones, "The Emerging Pattern of China's Economic Revolution," An Economic Profile of Mainland China, Vol. I, p. 93, table 11.

Table 4. Estimates of 1964-70 Chinese Grain Production

Year	Production (million metric tons)
1964...............	190
1965...............	195
1966...............	190
1967...............	215
1968...............	200
1969...............	205
1970...............	220

Source: U.S. Department of Agriculture, Foreign Agricultural Service, Foreign Agriculture, Washington, D.C., 1971.

communal organization, and a generally unmotivated peasantry, culminated in major food shortages throughout the northern industrial regions. The accompanying famine of the early 1960's was estimated to have set back population growth by as many as 40 to 60 million people as a result of lowered fertility and life-expectancy levels.1/ Inevitably, Mainland China's stockpiles of grain reserves were quickly depleted. At this point, in late 1960, the Chinese Government moved to allay the crisis by importing substantial quantities of Canadian and Australian wheat (table 2). More than 6.5 million tons were imported in the first 2 years, most of it going to feed the starving populations of Heilungkian, Kirin, Liaoning, Shantung, and Hopeh Provinces. Evidently the rice-rich southern areas were not so severely affected as were the northern wheat regions.

Return to Normalcy

By 1962, a year after the reversal of the policies of the Great Leap Forward, the central government had once again redirected the thrust of its agricultural management program. Effective control and planning responsibilities were returned to the small production brigades (20 to 30 families) in the hope that incentives and outputs would be restored at least to their levels prior to the Great Leap Forward. In addition, the free-market system of small private plots and state-subsidized hog-raising was reinstituted under the new policy. Very gradually, grain output began to trend upward again (table 3).

New programs of chemical fertilization, increased mechanization, water conservation, and irrigation undoubtedly accounted for the increased production. However, loss of wheatland due to increased construction and conversion to cotton crops may have partially offset the potential gains of the new agricultural modernization program. In fact, it has been argued that this

1/ Edwin F. Jones, "The Emerging Pattern of China's Economic Revolution," in An Economic Profile of Mainland China, Vol. I, p. 81.

factor alone may have accounted for the average annual loss of .93 million tons of wheat for the decade of the 1960's1/ (table 5).

Mainland China's Grain Trade

Mainland China has continued to export substantial quantities of rice and soybeans while it has been importing wheat. In 1964 Ch'en Ming, then director of the Third Bureau of Peking's Ministry of Foreign Trade, stated that: "If we import wheat, we can export soybeans and rice and other processed food grain -- and the price for rice and soybeans is higher than for wheat. This is a good means, in other words, of making money."2/ This commonly advanced argument to the effect that China has simply been taking advantage of competitive relationships within the world grain markets by selling rice dearly and buying wheat cheaply may be valid in principle, but was not so in practice. The total value of China's 1960-67 rice exports (rice value per metric ton being roughly twice that of wheat) amounted to some US$787 million, whereas the total c.i.f. value of wheat imports was figured to be approximately US$2.56 billion, well over three times the total value of rice exports.3/

During 1961-62 to 1965-66 China had an unfavorable trade balance in grains of 24.5 million metric tons, or an annual average of nearly 5 million tons.4/

Thus, it is apparent that whatever the foreign exchange benefits resulting from the price differences,

1/ Feng-wah Mah, Why China Imports Wheat, reprinted from The China Quarterly, January-March 1971, London, 1971, pp. 126-127.
2/ Dick Wilson, "Interview with Ch'en Ming," quoted by Feng-wah Mah in Why China Imports Wheat (London: The China Quarterly, 1971), p. 116.
3/ Feng-wah Mah, Why China Imports Wheat, p. 119.
4/ Robert L. Price, "International Trade of Communist China 1950-65" in An Economic Profile of Mainland China, p. 601.

Table 5. Estimated Reduction of Wheatland and Potential Wheat Output Forgone, 1962-67

Year	Wheat area	Reduction as compared with 1950-58 average	Wheat yield (m.t. per 1,000 ha.)	Potential wheat output forgone (1,000 m.t.)
	------- 1,000 ha. -------			
1950-58 (avg.)...	25,725	--	823	--
1962.............	24,400	1,325	870	1,153
1963.............	24,200	1,525	900	1,373
1964.............	25,500	225	1,000	225
1965.............	25,000	725	900	653
1966.............	24,500	1,225	850	1,041
1967.............	24,500	1,225	940	1,151

Source: Feng-wah Mah, Why China Imports Wheat, p. 126.

they were more than offset by the necessity of importing substantially greater quantities of wheat than the volume of rice exports.

Chinese wheat imports should rather be viewed as evidence of an imbalance between production and consumption demands. Although aggregate grain harvests have been increasing in the recent past, reaching a record level of 220 million tons in 1970, the population has similarly been expanding.1/ Per capita consumption is still below the decade preceding the Great Leap Forward (table 3).

Not surprisingly, the general trend of Chinese wheat imports has been downward in the past 5 years (see table 2). The 1965 level of 6.3 million tons decreased in 1970 to 3.86 million tons, and this general trend is expected to continue so long as the rate of agricultural growth equals or exceeds that of population. On balance, it would appear that total grain imports have represented only a marginal share of total Chinese grain consumption, accounting for from 3 to 4 percent of total grain supply from 1961 to 1971.2/

Agricultural Self-Sufficiency: Problems and Prospects

Apart from the central government's future policies relating to agricultural development, including the level of new agricultural investment, the key factor to be taken into consideration in the determination of prospective Chinese wheat supply shortages will be

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1/ U.S. Department of Agriculture, The Agricultural Situation in Communist Areas, Review of 1970 and Outlook for 1971, Economic Research Service Foreign Bulletin 314, p. 32.

2/ U.S. Department of State, Issues in United States Foreign Policy, No. 4 -- Communist China, Publication 8499, East Asian and Pacific Series 173 (Washington, D.C.: Government Printing Office, December 1969), p. 17.

the effectiveness of China's population control measures. In the recent past, high national priority has been assigned to programs designed to reduce the rate of population growth. "Barefoot doctors," for example, traverse the countryside disseminating birth control information and devices, while late marriages are being encouraged in an effort to stem the tide of population expansion.

Mainland China shares many common problems with the other developing nations of the world which are trying to reduce the rate of their population growth. In modernizing societies this has traditionally come about over a long period of time -- usually three to four generations. The Japanese lowered their growth rate from 2.5 to 1 percent in a span of four generations. In the initial period of modernization, while birth rates remain high, the death rate drops off as a result of improved medical and health facilities. Naturally, the total population growth increases in response to the slowing of the death rate. (China is now at this stage.) Eventually, the death rate stabilizes around a low level, and finally the birth rate declines as new social mores are adopted. A quick reduction of the growth rate accompanies this final step.

The operations of this phenomenon are demonstrated in the model of Mainland China's population growth in table 6, showing actual and projected data at 5-year intervals for the period 1948 to 1978. It should be emphasized that this is a model and does not constitute a judgmental projection of population growth in China.

Life expectancy is estimated to have increased in 1953-58 from 40 to 50 years, and to have fallen back to 40 years in the 1958-63 period because of the food shortages referred to earlier. Life expectancy is estimated to increase from 50 years in 1968 to 55 years in 1978. The number of women in the child-bearing age group of 15 to 44 years is estimated to increase, but their fertility is estimated to decrease from 200 births per thousand in 1958 to 145 in 1978.

Table 6. Model of China's Population Growth[a/]

Midyear	Life expectancy (yrs.)	Number of women aged 15 to 44 (millions)	Ann. births per 1,000 women aged 15 to 44	Population (millions)				Average annual growth (pct.)
				0 to 14	15 to 59	Over 59	Total	
1948.....	--	--	--	181	317	37	535	--
1953.....	40.0	119	196	209	331	43	583	1.8
1958.....	50.0	124	200	254	351	49	654	2.3
1963.....	40.0	130	176	270	368	52	690	1.1
1968.....	50.0	142	195	298	412	58	768	2.2
1973.....	52.5	163	173	319	466	64	849	2.0
1978.....	55.0	184	145	343	510	72	925	1.8

Age group	Absolute increase (mil.)		Percentage increase	
	1948-63	1963-78	1948-63	1963-78
0 to 14.......	59	73	51	26
15 to 59......	51	142	15	39
Over 59.......	15	20	35	44
Total........	155	235	29	34

a/ This model ages and reverse-ages the 1953 census population, employing U.N. life table values and assuming life expectancies and fertilities appropriate to obtain the total population estimated or projected by Peking.

Source: Edwin F. Jones, "The Emerging Pattern of China's Economic Revolution," in An Economic Profile of Mainland China, Vol. I, table 1, p. 93.

The average annual population growth rate increased from 1.8 percent in 1948-53 to 2.3 percent in 1953-58, and declined to 1.1 percent in 1958-63 because of the abnormal fertility and death rates due to the drought. However, in the more normal period 1963-68, the average annual growth rate was 2.2 percent, and declines successively in the following two 5-year periods to 2.0 percent and 1.8 percent.

By the year 2000 Mainland China will have completed its second generation of modernization. To compensate for the continued lowering of the death rate, the compaction of the above process within such an abbreviated timeframe would entail the wholesale acceptance of a population limitation program with a reproduction rate near the zero level. That the Chinese Government will be able to achieve such a goal by the turn of the century is unlikely. However, policy enforcement in totalitarian states is sometimes more effective than in less authoritarian regimes. The final outcome, regardless of this consideration, still remains in doubt.

Other things being equal, the long-run productivity of Chinese agriculture may be viewed as one of increasing returns to the scale of investment in four areas: fertilizer imports and production capacity, research and development of high-yield seed strains, irrigation and water conservation programs, and extensive utilization of mechanized farm machinery where feasible.

Even by the most modest of population projections (1.5 percent average growth rate), Mainland China is seen to have a population of over 1 billion by 1985 and of 1.25 billion by 2000. Merely to remain at the present level of grain consumption, which is assumed to be in the neighborhood of the subsistence level of 250 kilograms annually per capita, Chinese agriculture must produce 275 million tons of grain by 1985 and 344 million tons by 2000. In percentage terms, that amounts to a 25 percent increase in total output in less than 15 years, and a 64 percent increase in under 30 years (table 7).

Table 7. Illustrative Projections of Population and Grain Production in China, 1970-2000

Growth rate	1970	1975	1985	2000
(pct.)	In thousands			
Population				
1.5.........	800,000	861,840	1,000,160	1,250,480
1.6.........	800,000	866,080	1,015,040	1,287,920
1.7.........	800,000	870,320	1,030,160	1,326,560
1.8.........	800,000	874,640	1,045,440	1,366,240
1.9.........	800,000	878,960	1,060,960	1,407,040
2.0.........	800,000	883,280	1,076,720	1,449,120
2.1.........	800,000	887,600	1,092,640	1,492,320
2.2.........	800,000	891,920	1,108,800	1,536,800
2.3.........	800,000	896,320	1,125,200	1,582,560
2.4.........	800,000	900,720	1,141,760	1,629,600
2.5.........	800,000	905,120	1,158,640	1,678,080
1.5.........	850,000	915,705	1,062,670	1,328,635
1.6.........	850,000	920,210	1,078,480	1,368,415
1.7.........	850,000	924,715	1,094,545	1,409,470
1.8.........	850,000	929,305	1,110,780	1,451,630
1.9.........	850,000	933,895	1,127,270	1,494,980
2.0.........	850,000	938,485	1,144,015	1,539,690
2.1.........	850,000	943,075	1,160,930	1,585,590
2.2.........	850,000	947,665	1,178,100	1,632,850
2.3.........	850,000	952,340	1,195,525	1,681,470
2.4.........	850,000	957,015	1,213,120	1,731,450
2.5.........	850,000	961,690	1,231,055	1,782,960
	In thousands of metric tons			
Grain production				
1.5.........	220,000	237,006	275,044	343,822
1.6.........	220,000	238,172	279,136	354,178
1.7.........	220,000	239,338	283,294	364,804
1.8.........	220,000	240,526	287,496	375,716
1.9.........	220,000	241,714	291,764	386,936
2.0.........	220,000	242,902	296,098	398,508
2.1.........	220,000	244,090	300,476	410,388
2.2.........	220,000	245,278	304,920	422,620
2.3.........	220,000	246,488	309,430	435,204
2.4.........	220,000	247,698	313,984	448,140
2.5.........	220,000	248,908	318,626	461,472

Mainland China presently supports one-quarter of the world's population on 7.8 percent of the world's arable land.1/ At an average 2 percent population growth rate, the agricultural sector in 2000 will have to support 1.5 billion people -- the equivalent of nearly half the world's present population. At a comparable agricultural growth rate, still remaining at a subsistence level, Chinese agriculture must be capable of producing at a level roughly 80 percent greater than at present (table 7).

When the future needs of the expanding industrial sector are considered, the strains placed on capital resources for even such conservative estimates as these represent nearly insurmountable obstacles. If Chinese agricultural output could be augmented by labor-intensive development, future uncertainties would be lessened. However, diminishing returns on the productivity of Chinese agricultural labor set in dozens, if not hundreds, of years ago. Only by future large-scale capital-intensive development that concentrates on increasing the production of chemical fertilizers and on developing suitable new strains of high-yield seeds can this vital sector of the Chinese economy hope to remain self-sufficient.

The trend toward increased use of chemical fertilizers in Mainland China is demonstrated in table 8, which shows that total availability has increased from slightly over 400,000 metric tons in 1952 to 8.5 million in 1966. It is of interest to note that whereas there has been a significant growth in chemical fertilizer production in recent years, the proportion of total availability from indigenous production has been declining and was less than 60 percent in 1966. However, it is understood that Mainland China has resources of phosphates, one of the principal sources of chemical fertilizer nutrients, and also has the basic natural resources for the production of nitrogen. However,

1/ Marlon R. Larsen, "China's Agriculture Under Communism," in An Economic Profile of Mainland China, Vol. I, p. 199.

Table 8. Production and Imports of Chemical Fertilizer by Mainland China, 1941 and 1949-66[a]

(In thousands of metric tons)

Year	Total nitrog-enous	Phosphatic and other	Total	Imports, all types	Total avail-ability
1941...	227	--	227	b/	b/
1949...	27	--	27	b/	b/
1950...	70	--	70	b/	b/
1951...	134	--	134	b/	b/
1952...	188	6	194	239	433
1953...	249	--	249	343	592
1954...	321	--	321	579	900
1955...	324	21	345	875	1,220
1956...	563	100	663	837	1,500
1957...	683	120	803	997	1,800
1958...	900	344	1,244	1,456	2,700
1959...	1,390	375	1,765	1,190	2,955
1960...	1,960	500	2,460	860	3,320
1961...	1,080	320	1,400	883	2,283
1962...	1,600	500	2,100	1,000	3,100
1963...	2,200	700	2,900	1,700	4,600
1964...	2,600	900	3,500	1,030	4,530
1965...	c/	c/	4,500	2,500	7,000
1966[d].	c/	c/	5,000	3,500	8,500

a/ These data, most of which are estimates, are based on sources in the U.S. Department of Agriculture.
b/ Not available.
c/ Included in totals.
d/ Preliminary.

Source: Marion R. Larsen, "China's Agriculture Under Communism," in An Economic Profile of Mainland China, Vol. I, p. 246.

whether they are produced indigenously or imported, chemical fertilizers must compete with other sectors of the economy for scarce capital or for scarce foreign exchange.

It remains to be seen whether or not the Chinese people are capable of such prodigious accomplishments. The people of Han, as they refer to themselves, have traditionally been noted for their austerity, perseverance and dedication. The fact that prior to 1966 they managed to maintain a favorable balance of trade while repaying the bulk of their debt to the U.S.S.R. gives some indication of their capabilities in the field of economic management. Nevertheless, it appears that Communist regimes in general have a brown thumb when it comes to agricultural resource development. However, no sufficient data base exists for predicting the future of Chinese agriculture with any degree of confidence. The bulk of the Chinese grain deficits in the past decade resulted from the simultaneous combination of a number of totally unpredictable factors.

In late 1969, the Chinese Government released the details of its most recent economic development plan. Cognizant of China's most pressing problems, the program shied away from the former emphasis upon neo-Stalinist heavy industrial development in favor of an equipollent consumer-oriented program which concentrates on the expanded development of the light industrial and agricultural sectors of the Chinese economy. The agricultural development plan called for the decentralized production of new farm machinery and chemical fertilizer on a local basis. The administration of agricultural organization was similarly localized, albeit on a limited scale, in the hope that it would thus be more responsive to local conditions and needs.

Despite reports to the contrary, it appears that the peasants' private plots continue to be officially sanctioned. In retrospect, it may reasonably be concluded that the all-important question of agricultural incentives has yet to be dealt with efficiently on any basis other than a quasi-profit one. With the

negligible prospect of a fundamental change in human nature taking place, the Chinese regime will likely have to be content with the existence of a limited sphere of private financial activity within the confines of its economic order.

In the final analysis, however, responsibility for the success or failure of the government's policies rests with the peasants' acceptance of these policies. As past studies have shown, sinified Marxist-Leninist policies, when implemented, are likely to be couched in purely ideological terminology and perspective. The residuary mores of China's Confucian mentality, which have persisted through well over 3 millennia of cultural continuity, may prove to be the most formidable of obstacles to the achievement of so-called Communist ends. Thus, the Confucian concept of the extended family and the inherent cultural inhibitions associated with programs which attempt to update the painstakingly developed, time-honored methods of the rural majority's agricultural heritage may frustrate the regime's population control and agricultural development programs for an indeterminable number of years.

Although the Chinese people appear to have adapted relatively well to the political, economic and social changes in their society since 1949, the possibility of a future cultural backlash should not be discounted. The severance and eradication of a cultural legacy as profoundly ingrained as China's is decidedly not an easy task. As such, the long-run stability of the Chinese economy, with its concomitant ramifications in domestic agricultural and industrial production, cannot be predicted with any degree of certainty.

Grain Import Prospects

From the foregoing, two basic conclusions emerge: that near-term and long-term imports of grains by Mainland China cannot be projected with any degree of confidence, and that failure of food production growth rates to equal or exceed population growth rates could result in very substantial food deficits.

In the absence of a reliable basis for projection, tables 7 and 9 have been constructed to illustrate the quantitative implications of alternative rates of growth of population and of grain production. Table 7 projects population and grain production for 1975, 1985, and 2000 under various assumed rates of growth, employing alternative population assumptions for the base year 1970 of 800 million and 850 million. The grain production base of 220,000 is as shown in table 4.

Table 9 calculates the grain balance of Mainland China in 1975, 1985, and 2000 under assumed relative rates of growth for grain production and population. These calculations employ for the 1970 base year an assumed population of 800 million, 220 million tons of grain production, and per capita consumption of 275 kilograms per annum. This per capita consumption is held constant as a basis for calculating the aggregate grain requirements at variable levels of population. Thus when growth rates for the grain production and population components are in equilibrium, so also are production and requirements.

Starting from these premises, an average annual growth rate of 2.2 percent in population and of 2 percent in grain production would result in a 1975 deficit of 2.4 million metric tons. A continuation of this relationship to 1985 and 2000 would result in a deficit of 8.8 million tons and 24.1 million tons, respectively. Population and grain production growth rates of 2.5 percent and 2 percent, respectively, would result in a deficit of 63 million tons in 2000.

While deficits of such a magnitude could conceivably occur, they should be regarded as unlikely and more or less theoretical in terms of their implications for levels of grain imports. They are theoretical, first of all, because it is unrealistic to anticipate that Mainland China could accommodate the foreign exchange costs of grain imports at such levels within its overall balance of payments. It would be equally unrealistic to assume that other governments would provide such volumes of grain exports to China on

Table 9. Calculated Net Grain Balance of Mainland China at Various Growth Conditions, 1975, 1985, and 2000

(In millions of metric tons of grain)

Year and grain growth rates (percent)	Population growth rates (percent)										
	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5
1975											
1.5	0	(1.2)	(2.3)	(3.5)	(4.7)	(5.9)	(7.0)	(8.3)	(9.5)	(10.7)	(11.9)
1.6	1.2	0	(1.2)	(2.3)	(3.5)	(4.7)	(5.9)	(7.1)	(8.3)	(9.5)	(10.7)
1.7	2.3	1.2	0	(1.2)	(2.4)	(3.6)	(4.8)	(5.9)	(7.1)	(8.4)	(9.6)
1.8	3.5	2.3	1.2	0	(1.2)	(2.4)	(3.6)	(4.8)	(6.0)	(7.2)	(8.4)
1.9	4.7	3.5	2.4	1.2	0	(1.2)	(2.4)	(3.6)	(4.8)	(6.0)	(7.2)
2.0	5.9	4.7	3.6	2.4	1.2	0	(1.2)	(2.4)	(3.6)	(4.8)	(6.0)
2.1	7.1	5.9	4.7	3.6	2.4	1.2	0	(1.2)	(2.4)	(3.6)	(4.8)
2.2	8.3	7.1	5.9	4.8	3.6	2.4	1.2	0	(1.2)	(2.4)	(3.6)
2.3	9.5	8.3	7.1	6.0	4.8	3.6	2.4	1.2	0	(1.2)	(2.4)
2.4	10.7	9.5	8.4	7.2	6.0	4.8	3.6	2.4	1.2	0	(1.2)
2.5	11.9	10.7	9.6	8.4	7.2	6.0	4.8	3.6	2.4	1.2	0
1985											
1.5	0	(4.1)	(8.2)	(12.4)	(16.7)	(21.1)	(25.4)	(29.9)	(34.4)	(38.9	(43.6)
1.6	4.1	0	(4.2)	(8.4)	(12.6)	(17.0)	(21.3)	(25.8)	(30.3)	(34.8)	(39.5)
1.7	8.2	4.2	0	(4.2)	(8.5)	(12.8)	(17.2)	(21.6)	(26.1)	(30.7)	(35.3)
1.8	12.5	8.4	4.2	0	(4.3)	(8.6)	(13.0)	(17.4)	(21.9)	(26.5)	(31.1)
1.9	16.7	12.6	8.5	4.3	0	(4.3)	(8.7)	(13.2)	(17.7)	(22.2)	(26.9)
2.0	21.1	17.0	12.8	8.6	4.3	0	(4.4)	(8.8)	(13.3)	(17.9)	(22.5)
2.1	25.4	21.3	17.2	13.0	8.7	4.4	0	(4.4)	(9.0)	(13.5)	(18.1)
2.2	29.9	25.8	21.6	17.4	13.2	8.8	4.4	0	(4.5)	(9.1)	(13.7)
2.3	34.4	30.3	26.1	21.9	17.7	13.3	9.0	4.5	0	(4.6)	(9.2)
2.4	38.9	34.8	30.7	26.5	22.2	17.9	13.5	9.1	4.6	0	(4.6)
2.5	43.6	39.5	35.3	31.1	26.9	22.5	18.1	13.7	9.2	4.6	0
2000											
1.5	0	(10.3)	(20.9)	(31.8)	(43.1)	(54.6)	(66.5)	(78.7)	(91.3)	(104.3)	(117.6)
1.6	10.3	0	(10.6)	(21.5)	(32.8)	(44.3)	(56.2)	(68.4)	(81.0)	(94.0)	(107.3)
1.7	20.9	10.6	0	(10.9)	(22.1)	(33.7)	(45.6)	(57.8)	(70.4)	(83.3)	(96.7)
1.8	31.8	21.5	10.9	0	(11.2)	(22.8)	(34.7)	(46.9)	(59.5)	(72.4)	(85.8)
1.9	43.1	32.8	22.1	11.2	0	(11.6)	(23.5)	(35.7)	(48.3)	(61.2)	(74.5)
2.0	54.6	44.3	33.7	22.8	11.6	0	(11.9)	(24.1)	(36.7)	(49.6)	(63.0)
2.1	66.5	56.2	45.6	34.7	23.5	11.9	0	(12.2)	(24.8)	(37.8)	(51.1)
2.2	78.7	68.4	57.8	46.9	35.7	24.1	12.2	0	(12.6)	(25.5)	(38.9)
2.3	91.3	81.0	70.4	59.5	48.3	36.7	24.8	12.6	0	(12.9)	(26.3)
2.4	104.3	94.0	83.3	72.4	61.2	49.6	37.8	25.5	12.9	0	(13.3)
2.5	117.6	107.3	96.7	85.8	74.5	63.0	51.1	38.9	26.3	13.3	0

Note: This table, illustrative rather than definitive in character, is designed to give an indication of the relative magnitude of future Chinese agricultural production deficits and surpluses under variable relative grain production and population growth rates. The 1.5 to 2.5 percent growth rates are projected upon a 1970 grain production estimate of 220 million tons as applied to a 1970 population estimate of 800 million, with an implied annual per capita grain consumption requirement of 275 kilograms.

concessional terms over a continued period of time. If a dearth of natural and other economic resources should result in a long-term negative imbalance between grain production and population growth rates, it is reasonable to assume that food shortages themselves will become a constraining influence on population growth.

Taking into account the present stage of economic development and income of Mainland China and the probability that per capita income growth in the future will be very gradual, there does not appear to be any realistic basis for projecting continuing large volumes of grain imports. As in the case of all major less developed countries, Mainland China can be expected to pursue a policy of self-sufficiency in basic foodstuffs, so as to maximize the availability of foreign exchange resources for capital goods and basic materials required for agricultural and industrial expansion.

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II. POTENTIAL COKING COAL EXPORTS FROM MAINLAND CHINA

Introduction

Potential Japanese purchases of Mainland Chinese metallurgical-quality bituminous coal on a large scale could present a serious challenge to the future competitive position of premium low-volatile and medium grades of U.S. coking coal in the Japanese market. Mainland China has large reserves of coking coal, and is one of the world's leading coal producers. It has also exported substantial quantities of coal to Japan, although such exports virtually ceased after 1967.

Japanese imports of Chinese coal in 1965-67 totaled 2.4 million tons. Coals designated "heavy coking" and "bituminous coal for coking" with an ash content of less than 8 percent amounted to a total of less than 30,000 metric tons over a 3-year period. The higher ash coals comprised the bulk of Japan's purchases from China, accounting for well over 1 1/2 million tons of coal classified "heavy coking with ash over 8 percent," and 635,680 tons of "bituminous coal for coking with ash over 8 percent" (table 10). Since 1967, Japan's coal trade with China has been restricted to anthracite grades, with the exception of one very small purchase of bituminous coal in late 1968.

Chinese Coal Resources

Table 11 shows estimates of Mainland China's coal reserves made before and after World War II, but

Table 10. Amounts and Value[a/] of Japanese Imports of Bituminous Coking Coal From Selected Sources of Supply, 1965-67

Year and country of origin	Heavy coking				Coal for coking			
	Ash not over 8%		Ash over 8%		Ash not over 8%		Ash over 8%	
	Metric tons	Value/ ton	Metric tons	Value/ tons	Metric tons	Value/ ton	Metric tons	Value/ ton
1965								
Australia.	1,745,078	4.80	2,854,765	4.85	774,524	4.83	1,245,837	4.83
Canada....	78,832	5.23	661,886	5.10	--		10,276	5.60
M. China..	6,510	4.70	391,423	4.71	--		336,553	4.77
U.S.......	6,744,478	6.66	27,089	6.63	--		132,225	6.70
1966								
Australia.	1,832,724	4.67	3,511,927	4.83	761,548	4.77	1,946,660	4.68
Canada....	13,758	5.54	759,275	5.17	--		64,531	5.33
M. China..	--		561,939	4.79	5,702	4.87	89,205	4.84
U.S.......	6,939,901	6.67	41,500	6.58	75,792	6.92	10,324	6.46
1967								
Australia.	1,718,008	4.48	3,627,590	4.78	1,293,351	4.65	2,344,234	4.61
Canada....	14,872	5.90	757,609	5.34	23	13.83	42,459	5.49
M. China..	7,180	4.83	664,041	4.78	9,860	4.89	209,922	4.75
U.S.......	9,896,431	6.70	28,388	5.93	192,247	6.77	--	

a/ Average value in thousands of yen per metric ton.
Source: Trade of Japan (Tokyo), December 1965. Japan's Exports and Imports (Tokyo), December 1966, December 1967.

Table 11. Estimates of China's Reserves of Coal
(In billions of metric tons)

Year	Source	Category	Estimate
1931...	National Geological Survey of China 1916-1931: A Summary, p. 7	All grades (China proper)	260
1935...	T.F. Hou, NGSC	Anthracite; bituminous (China proper)	239
1945...	C.C. Pai, NGSC	All grades (China plus Manchuria)	444
1948...	U.S. Department of Interior, Bureau of Mines, "Mineral Resources of China," in Foreign Minerals Survey, January 1948	All grades (China plus Manchuria)	283
1957...	John Ashton, "Development of Electric Energy Resources in Communist China," in An Economic Profile of Mainland China, Vol. I, p. 303.	All grades (China plus Manchuria)	1,500
1960...	U.S. Department of the Interior, Geological Survey Bulletin #1136	Anthracite; bituminous and subbituminous (China plus Manchuria)	1,011

Source: As stated except for 1935 and 1945 figures, which were supplied by Joseph Liamari, Bureau of Mines, Coal Export Division.

prior to the takeover by the Communist regime, and estimates appearing in publications in 1959 and 1960 reportedly based on geological investigations made by the Communists after the takeover.

Virtually all of Mainland China's reserves are anthracite, bituminous, and subbituminous. Reserves of lignite are negligible. In the pre-Communist period, reserve estimates ranged from 239 billion to 444 billion metric tons. The latter include reserves in Manchuria, which are estimated at 23 billion metric tons. On the other hand, the more recent estimates range from roughly 1 billion to 1.5 billion metric tons. Even if the lower of the two is accepted, the coal reserves of Mainland China would be approximately the same as those of the United States and the U.S.S.R., and would account for over one-quarter of total world reserves.1/

Generally, Chinese bituminous coal is believed to be fair to good in quality and low in sulfur, with an ash content ranging from 4 to 15 percent, and a caloric value averaging from 12,000 to 13,000 B.t.u.'s per pound.2/ For the most part, however, the lack of coal cleaning plants causes the coal which reaches most domestic and foreign markets to be of a lower overall quality than would otherwise be the case.

The qualities of Chinese coals may be judged from the data in table 12, which reports data on analyses of Chinese coals based on actual samples delivered and tested for the most part in the 1920's and 1930's. In terms of Japanese requirements for coking coals, it is of interest to note that a large number of samples have relatively low volatile matter content and most samples have a sulfur content of less than 1 percent. The ash content of a large number of

1/ U.S. Geological Survey, Coal Reserves of the United States - A Progress Report, January 1, 1960, Bulletin 1136, Table 5, pp. 91 and 92.
2/ John Ashton, "Development of Electric Energy Resources in Communist China," in An Economic Profile of Mainland China, Vol. I, p. 302.

Table 12. Analyses of Chinese Coals

Item No.	Continent or island	Country	Subdivision	Region or mine	Bed	Rank as calculated (or as marked where not given)[1]	Size or other description	Number of samples	Kind of sample	Condition of sample	Proximate analysis, percent: Moisture	Volatile matter	Fixed carbon	Ash	Sulfur, percent	Calorific value, B.t.u. per pound	Range of proximate analyses, percent: Moisture Low	Moisture High	Volatile matter Low	Volatile matter High	Fixed carbon Low	Fixed carbon High	Ash Low	Ash High	Range of sulfur, percent: Low	High	Range of calorific values, B.t.u. per pound: Low	High	Ash fusion temperature, °F.	Source of analysis[2]	Item No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1
57	Asia	China	Heilungkiang	Luqen						A							13.51	26.21	31.15	37.63	34.50	41.62	6.12	7.73			9,300	11,300			57
58	do	do	do	Neraing						A							3.54	14.35	14.60	44.34	16.80	52.83	9.00	9.60				11,750			58
59	do	do	do	Pa..		Mvb		1		A	12.38	20.89	53.73	13.00		11,700															59
60	do	do	do	Tsingtung						A							.67	10.35	37.41	39.75	32.22	50.62	4.56	17.64			9,000	11,900			60
61	do	do	do	Tehh						A							2.64	7.31	2.67	4.65	12.57	62.29	22.53	49.17			7,750	11,500			61
62	do	do	do	Tuncheng		Hvab		1		A	9.12	27.46	37.72	25.66		10,900															62
63	do	do	do	Tunejen						A							.50	10.99	11.99	72.07	37.35	74.61	12.90	19.97			8,450	13,900			63
64	do	do	Honan	Anyang		Mvb		1		A	.46	23.79	60.73	15.02	0.85	13,250															64
65	do	do	do	Meihsien		Mvb		1		A	.30	16.40	32.46	50.82		7,600															65
66	do	do	do	Paan						A							2.45	2.54	7.29	15.55	72.30	77.06	9.61	13.30			13,150	13,800			66
67	do	do	do	Sunan		An		1		A	2.97	3.66	71.16	29.31		11,900														[illegible]	67
68	do	do	do	Wuan		An		1		A	4.25	5.83	75.98	13.82		12,700														[illegible]	68
69	do	do	*Hopei	Changsing						A							.11	1.84	20.99	34.62	51.58	70.66	3.17	23.50	0.78	2.50	11,800	14,500		[illegible]	69
70	do	do	do	Kang Shan		Sa				A	3.14	7.60	62.72	26.54		11,800														[illegible]	70
71	do	do	do	do						A							1.15	5.02	7.27	14.32	49.42	84.67	4.51	30.23	.33	.53	7,350	14,700		[illegible]	71
72	do	do	do	Lin Cheng						A							1.30	2.87	26.88	36.90	53.22	72.61	4.09	23.60	.73	4.07	10,600	14,000		[illegible]	72
73	do	do	do	Luan		Hvab				A	2.25	35.19	47.09	15.47		11,600														[illegible]	73
74	do	do	do	do						A							.32	2.60	29.31	40.22	42.98	57.36	6.71	25.40	.87	1.39	10,550	13,750		[illegible]	74
75	do	do	do	Hsinglung						A							.23	1.05	29.52	35.26	61.69	57.67	8.30	26.22			10,350	13,800		[illegible]	75
76	do	do	do	Shabo						A							2.73	3.50	5.89	12.93	48.48	86.32	4.30	16.34			12,750	14,250		[illegible]	76
77	do	do	do	Tsu						A							.24	1.98	17.94	34.43	53.86	73.62	4.96	30.99	.37	2.80	12,250	14,900		[illegible]	77
78	do	do	do	Wanping						A							.12	4.55	2.19	34.33	56.06	87.75	4.37	37.52	.30	.49	8,450	11,850		(5)	78
79	do	do	[illegible]	Luting		Lvb		1		A	.43	14.12	63.43	22.02		12,200														[illegible]	79
80	do	do	Hunan	Chen		An		1		A	2.22	7.48	77.88	12.42		13,300														[illegible]	80
81	do	do	do	Laiyang						A							1.16	2.00	6.19	6.55	51.60	93.79	8.56	9.45			13,750	15,500		[illegible]	81
82	do	do	do	Liling						A							2.00	4.80	29.79	41.26	46.51	54.30	3.35	15.62	.87	1.27	11,250	13,400		[illegible]	82
83	do	do	do	Siangsiang						A							.67	2.34	14.02	27.13	60.45	74.17	7.80	25.92			11,220	14,200		[illegible]	83
84	do	do	do	Siangtan						A							.62	4.55	4.71	31.65	32.16	75.32	6.37	42.37	.65	.65	7,800	14,600		[illegible]	84
85	do	do	Hupei	Chunhsien		Sa		1		A	1.65	11.14	69.71	17.50		12,700														(5)	85
86	do	do	do	Huangmei		Mvb		1		A	.70	15.75	39.70	44.55		8,550														(5)	86
87	do	do	do	Yangsin		Sa		1		A	.35	12.43	70.42	16.60		13,000														(5)	87
88	do	do	Jehol	Chaoyang						A							.21	5.06	16.64	35.92	33.25	61.96	8.83	18.05	.19	.39	7,750	14,350		(5)	88
89	do	do	do	Fusin						A							2.04	6.96	22.62	32.61	50.16	75.27	3.13	21.65			12,300	13,500		(5)	89
90	do	do	do	Lungkua		Hvab		1		A	3.27	32.77	52.73	11.23		12,750														(5)	90
91	do	do	Kansu	Wuwei		Lvb		1		A	2.77	16.61	65.62	11.60		13,300														(5)	91
92	do	do	Kiangsi	Chuangen						A							.31	1.42	15.34	17.73	52.36	66.88	15.23	21.32			12,350	13,150		(5)	92
93	do	do	do	Pinghsiang						A							.76	1.22	26.43	33.23	41.95	62.02	3.63	22.65	.54	1.02	11,000	14,400		(5)	93
94	do	do	do	Tsinhsien						A							.25	2.17	6.75	36.16	43.42	70.34	13.37	49.44			7,800	12,300		(5)	94
95	do	do	Kiangsu	Kiangning		Hvab		1		A	.48	31.54	49.72	18.26		12,050														(5)	95
96	do	do	do	Luyang		Lvb		1		A	.36	14.50	62.65	22.45		12,150														(5)	96
97	do	do	do	Tungshan						A							1.86	1.91	32.51	36.94	42.29	51.46	8.79	22.34			10,650	12,600		(5)	97
98	do	do	do	Yihsing		Mvb		1		A	.40	16.94	49.19	33.47		10,400														(5)	98
99	do	do	Kirin	Fuchin		Mvb		1		A	.83	24.27	69.04	6.06		15,300														(5)	99
100	do	do	do	Hunchuen						A							0.53	10.52	42.70	45.99	30.60	34.47	12.86	13.30			8,000	8,850		(5)	100
101	do	do	do	Meshan						A							1.15	16.17	24.50	32.96	43.06	67.81	5.61	10.77			11,300	15,350		(5)	101
102	do	do	do	Mulong		Hvab		1		A	2.22	24.51	54.65	8.62		13,550														(5)	102
103	do	do	do	Nee Mo		Hvab		1		A	7.68	26.68	47.73	15.91		12,250														(5)	103
104	do	do	do	Yungchi													9.05	10.00	30.99	42.84	21.27	30.81	19.35	29.70						(5)	104
105	do	do	Kweichow	Chihchung						A							1.33	2.79	3.11	5.11	74.16	90.96	12.60	19.49			11,550	13,250		(5)	105
106	do	do	do	Kueiyang						A							.36	1.10	11.55	16.97	58.86	83.50	4.40	23.91			11,850	14,900		(5)	106
107	do	do	do	Pitsieh		Sa		1		A	3.06	5.54	70.80	22.48		11,650														(5)	107
108	do	do	do	Suancn		Sa		1		A	.60	12.15	79.20	8.05		14,350														(5)	108
109	do	do	do	Tating						A							1.35	5.10	4.52	17.16	69.77	83.55	10.45	37.10						(5)	109
110	do	do	do	Tsunyi		An		1		A	.60	6.20	76.26	16.94		12,800														(5)	110
111	do	do	do	Tungtze						A							.76	1.21	7.10	7.26	73.47	78.36	13.75	16.41			12,850	13,350		(5)	111
112	do	do	do	Tsekuen						A							.52	1.20	11.13	21.49	62.19	76.87	6.87	16.80			13,000	14,350		(5)	112
113	do	do	Kwangsi	Chuanhsien		Sa		1		A	2.76	11.54	59.56	26.12		11,100														(5)	113
114	do	do	do	Louncheng						A							2.95	6.45	8.12	14.53	59.40	80.58	6.75	23.60			11,650	13,900		(5)	114
115	do	do	do	Shunan						A							1.55	1.75	14.29	15.70	49.63	63.26	20.90	33.72			10,150	12,200		(5)	115
116	do	do	do	Tsinho						A							4.20	5.40	7.82	11.57	71.18	80.01	7.87	11.85			13,000	13,700		(5)	116
117	do	do	do	Tsankiang		Sa		1		A	1.25	13.28	78.65	6.82		14,450														(5)	117
118	do	do	Kwangtung	Chukiang						A							.70	2.12	11.30	16.60	55.93	80.86	4.17	26.25			10,950	14,900		(5)	118
119	do	do	do	Chang		Subb		1		A	15.55	42.77	35.25	6.43		8,200														(5)	119
120	do	do	do	Chungshan						A							11.37	11.47	23.86	36.83	26.47	30.42	21.05	25.33						[illegible]	120
121	do	do	do	Juyuan						A							1.30	1.30	12.80	29.02	53.58	57.86	11.80	34.02			13,100	13,500		[illegible]	121
122	do	do	do	Kaoming		Lvb		1		A	.60	12.07	37.03	50.30		7,700														[illegible]	122
123	do	do	do	Lechang						A							3.72	5.40	14.47	25.30	51.06	60.06	8.80	26.47			10,400	13,450		[illegible]	123
124	do	do	do	Lungmen				1		A	2.18	6.02	13.27	78.53		3,800														[illegible]	124
125	do	do	do	Yunfu		Sa		1		A	3.78	8.82	26.73	60.67		5,600														[illegible]	125
126	do	do	*Liaoning	Chi-an-chan Ssu		Hvab		1		A	4.93	29.36	19.79	6.08	.74	[2]13,900														[illegible]	126
127	do	do	do	Hsian		Sa		1		A	2.66	.12	78.01	14.16		12,800														[illegible]	127
128	do	do	do	Hsian..						A							.64	5.61	8.06	31.90	33.28	45.66	20.18	51.80	.48	.63	6,700	12,000		[illegible]	128
129	do	do	do	Kansu						A							1.76	2.14	12.77	45.12	22.28	45.30	19.06	42.51			5,650	10,900		[illegible]	129
130	do	do	do	Kungchangling		Hvab		1		A	6.28	7.21	47.77	6.66	.66	[2]13,100														[illegible]	130
131	do	do	do	Lao-tou-tu		Hvab		1		A	4.21	37.56	54.16	7.70	.73	[2]13,750														[illegible]	131
132	do	do	do	Ling-shan		Hvab		1		A	3.20	35.66	50.94	10.16	.86	[2]12,250														[illegible]	132
133	do	do	do	Pen-hsi						A							.37	17.16	8.31	35.20	30.62	56.22	8.50	32.80			7,450	11,150		[illegible]	133
134	do	do	do	Shang-tung		Hvab		1		A	2.62	36.72	50.76	9.70	.82	[2]11,100														[illegible]	134
135	do	do	do	Sinyi						A							.91	11.50	22.93	33.82	27.29	62.06	4.44	27.80	.56	2.30	9,100	12,250		[illegible]	135
136	do	do	do	Tehsin		Hvab		1		A	2.62	31.37	46.76	16.22	.95	[2]11,300														(4)	136

[1] See Explanation of Symbols

* Italic numbers in parentheses in this column refer to items listed under Sources of Analyses

[2] Source states that B.t.u. values are on moist, ash-free basis.

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continued--

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Table 12. Analyses of Chinese Coals continued--

Item No.	Continent or island	Country	Subdivision	Region or mine	Bed	Rank as calculated (sulfur calculated where not given)[1]	Size or other description	Number of samples	Kind of sample[1]	Condition of sample[1]	Proximate analysis, percent: Moisture	Volatile matter	Fixed carbon	Ash	Sulfur, percent	Calorific value, B t u per pound	Range of proximate analyses, percent: Moisture Low	Moisture High	Volatile matter Low	Volatile matter High	Fixed carbon Low	Fixed carbon High	Ash Low	Ash High	Range of sulfur, percent Low	Range of sulfur, percent High	Range of calorific values, B t u per pound Low	Range of calorific values, B t u per pound High	Ash fusion temperature, °F.	Source of analyses[2]	Item No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1
137	Asia	China	Liaoning	Taoan						A							0.63	7.31	17.14	22.31	46.87	52.56	25.10	35.36			10,650	12,800		(5)	137
138	do	do	do	Tasiman		Hvab		1		A	4.31	38.55	50.35	6.79	0.57	[2]14,600														(6)	138
139	do	do	do	Tung-shiang		Hvab		1		A	4.20	37.79	51.26	6.75	.76	[2]14,900														(6)	139
140	do	do	do	Wan-ta-wu		Hvab		1		A	4.25	37.20	51.16	7.49	.73	[2]14,500														(6)	140
141	do	do	Mongolia	Kulun		Hvcb		1		A	8.56	38.52	39.20	13.70		[2]10,650														(5)	141
142	do	do	Shansi	Chiehsiu		Mvb		1		A	.84	22.61	57.36	19.19		12,550														(5)	142
143	do	do	do	Fanchi						A							6.90	8.28	30.33	57.27	11.37	30.57	3.92	42.40						(5)	143
144	do	do	do	Hsiaoyi		Mvb		1		A	.23	24.66	69.36	5.75		14,750														(5)	144
145	do	do	do	Kuo		Hvab		1		A	.96	33.96	49.96	15.35		12,150														(5)	145
146	do	do	do	Pingting		An		1		A	1.93	6.21	79.75	12.11		13,300														(5)	146
147	do	do	do	Taiyuan		Lvb		1		A	.37	16.15	73.48	10.00		14,100														(5)	147
148	do	do	do	Tatung						A							.93	12.50	3.00	31.84	37.74	87.76	1.92	42.84	0.22	0.57	8,500	14,650		(5)	148
149	do	do	do	Tsincheng		An		1		A	1.05	7.85	82.35	8.75		14,050														(5)	149
150	do	do	do	Tsoyun		Mvb		1		A	5.15	24.19	56.61	14.05	.52	12,650														(5)	150
151	do	do	do	Wutai		Hvab		1		A	1.20	28.30	50.55	9.95		12,550														(5)	151
152	do	do	do	Yungchi		Lvb		1		A	.36	14.88	64.66	16.10		12,150														(5)	152
153	do	do	Shantung	Chang chiu						A							.45	.74	12.61	17.37	49.51	74.97	11.27	37.25			9,750	13,850		(5)	153
154	do	do	do	Poshan						A							.24	.70	13.25	23.90	63.18	76.23	5.50	17.12	.22	3.40	12,960	14,800		(5)	154
155	do	do	do	Yi						A							.07	.80	28.20	31.75	56.43	67.65	6.80	12.35	.66	1.71	12,450	14,400		(5)	155
156	do	do	Shensi	Fushih						A							1.19	2.27	32.21	36.83	43.62	55.75	5.15	21.56			10,800	13,550		(5)	156
157	do	do	do	Lu		Hvab		1		A	1.85	33.65	45.23	19.47		11,400														(5)	157
158	do	do	do	Tungkuan		Lvb		1		A	.42	17.39	64.34	17.85		12,850														(5)	158
159	do	do	do	Yenchuan						A							.84	2.70	44.58	36.01	44.39	49.86	17.32	18.90			10,950	11,750		(5)	159
160	do	do	do	Yiemun		Hvab		1		A	1.97	28.77	61.59	7.67		14,100														(6)	160
161	do	do	Sinkiang	Aksu						A							.72	1.09	15.66	19.87	72.43	79.91	1.25	10.12			13,850	15,400		(5)	161
162	do	do	do	Bai		Hvab		1		A	1.64	30.21	59.62	6.53		13,950														(5)	162
163	do	do	do	Kucha		Hvab		1		A	1.17	35.25	58.26	3.32		14,050														(5)	163
164	do	do	Suiyuan	Anpei						A							2.35	5.80	7.25	37.10	41.79	85.20	5.20	22.54			10,450	14,350		(6)	164
165	do	do	do	Kuyang		Hvcb, subb		1		A	8.41	29.90	35.15	26.54		8,900														(8)	165
166	do	do	Szechuan	An		Hvab		1		A	.40	31.44	56.01	12.15		13,450														(8)	166
167	do	do	do	Chien wei						A							.66	1.58	21.71	31.41	29.92	56.95	11.73	30.38			8,800	13,600		(5)	167
168	do	do	do	Chungking	Nei Lian			3	M	A							1.0	2.3	18.0	19.6	55.3	66.7	11.7	24.3	2.8	4.9	10,950	13,450		(7)	168
169	do	do	do	do	Nei Lian (thick)			4	M	A							1.0	1.8	16.8	18.4	61.5	70.3	10.5	20.4	2.2	4.1	11,700	13,550		(7)	169
170	do	do	do	do	Shuang Lian Tze (thin)			2	M	A							1.2	1.3	17.5	18.6	57.3	58.2	22.8	23.1	2.0	2.2	11,350	11,400		(7)	170
171	do	do	do	do	Ta Tu Lian (thin)			2	M	A							1.0	1.8	16.7	17.5	50.0	57.3	24.2	32.3	2.1	4.8	9,850	11,250		(7)	171
172	do	do	do	Hanyuan						A							1.07	3.29	5.53	12.36	58.88	74.74	11.89	32.02			10,100	13,700		(5)	172
173	do	do	do	Hochuan						A							.24	.42	15.77	17.71	67.15	69.02	16.27	20.76	1.85	3.40	12,400	14,100		(5)	173
174	do	do	do	Jenshou						A							.75	1.97	22.84	29.74	42.49	55.47	12.82	33.06			10,150	13,300		(5)	174
175	do	do	do	Kuangpei						A							.83	.85	17.29	31.99	33.85	70.92	5.30	46.90	.68	6.00	8,150	14,950		(5)	175
176	do	do	do	Omei						A							.76	6.77	10.80	25.86	32.11	74.28	3.27	27.45			11,250	15,050		(5)	176
177	do	do	do	Peng						A							.23	2.07	25.33	45.12	31.72	60.92	5.12	38.05			8,000	13,500		(5)	177
178	do	do	do	Pingshan						A							1.15	1.65	22.85	26.45	53.75	63.00	12.60	20.72			12,100	13,450		(5)	178
179	do	do	do	Pishan						A							.25	.84	17.39	24.99	55.96	67.76	13.02	18.62			12,550	13,550		(5)	179
180	do	do	do	Wei Yuan						A							.63	4.11	25.90	30.26	50.33	64.36	3.37	11.81			13,050	14,800		(4)	180
181	do	do	do	do	Wei Yuan mine	Hvab		1	M	A	2.1	30.1	60.8	7.0	.5	13,700														(7)	181
182	do	do	do		North Saolungtan			3	M	A							3.45	37.1	20.4	29.9	24.2	29.0	5.5	11.4	.6	1.6	6,150	6,650		(7)	182
183	do	do	do		North Tameitankoy	Lig		1	M	A	36.8	30.8	27.5	5.2	.7	6,700														(7)	183
184	do	do	do		Northeast Tameitankou	Lig		1	M	A	32.5	29.4	27.1	10.0	1.4	6,600														(7)	184
185	do	do	do		Southeast Tameitankou			3	M	A							35.9	36.3	28.9	31.0	22.2	28.3	5.3	5.7	.6	.7	6,450	6,750		(7)	185
186	do	do	do		Hsuo Tiao and Ta Tsao			2	M	A							2.3	4.1	18.7	20.2	57.0	64.5	14.5	18.7	2.8	4.6	11,450	12,750		(7)	186
187	do	do	do		Tolientzo			2	M	A							3.2	4.8	17.3	20.4	60.7	63.8	14.1	15.7	2.3	5.4	12,400	12,450		(5,7)	187
188	do	do	Yunnan	Ami		Hvab		1		A	.53	36.57	47.86	15.04		11,800														(5)	188
189	do	do	do	Cheng Kiang				5		A							.33	1.15	14.30	18.24	30.24	64.50	20.55	54.40			7,050	12,400		(5)	189
190	do	do	do	Kun Yang				3		A							.45	1.12	11.85	16.02	34.92	52.07	32.46	52.78			7,000	10,500		(5)	190
191	do	do	do	Sung-ming				5		A							.25	.30	16.36	16.55	80.06	80.44	2.76	3.22			15,150	15,250		(5)	191
192	do	do	do	Sung-ming and Yiliang				4		A							.25	.45	16.16	18.55	69.59	73.03	8.64	13.88			13,500	14,300		(4)	192
193	do	do	Formosa, Shinchiku Province	Kansai		Hvcb or subb				A	4.52	37.79	48.44	9.25		11,800														(8)	193
194	do	do	Taihoku Province														1.8	3.5	36.9	42.2	48.5	57.6	2.1	4.8			12,650	13,450		(8)	194
195	do	Federated Malay States				Subb		1		A	10.23	35.50	41.19	3.08	.38	9,550														(4)	195
196	do	do				Subb		1		A	21.06	36.70	39.26	1.04	.80	9,500														(4)	196
197	do	French Indo China				An	1½ by 2 inch	1	S	A	2.4	7.1	83.5	7.0	.7	13,800														(7)	197
198	do	do	Tonkin	Honcay						B									5	11	87	86	2.5	7		1	14,000	14,400		(8)	198
199	do	do	do	deKébao						A							2.7	4	5.8	7	64.3	85	4.8	25	.7	.8	11,200	13,600		(12)	199

[1] See Explanation of Symbols

[1] Italic numbers in parentheses in this column refer to items listed under Sources of Analyses

[2] Source states that B. t. u. values are on moist, ash-free basis.

continued--

Table 12. Analyses of Chinese Coals continued--

Explanation of Symbols

Column 7, rank:

Ma	meta-anthracite
An	anthracite
Sa	semianthracite
Lvb	low-volatile bituminous coal
Mvb	medium-volatile bituminous coal
Hvab	high-volatile A bituminous coal
Hvbb	high-volatile B bituminous coal
Hvcb	high-volatile C bituminous coal
Suba	subbituminous A coal
Subb	subbituminous B coal
Subc	subbituminous C coal
Lig	lignite
Brown	brown coal
Natc	natural coke

Column 10, kind of sample:

M	mine
T	tipple
B	breaker
D	delivered
S	stockpile
G	geologic

Column 11, condition of sample:

A	as-received
B	dry
C	air-dried

Sources of Analyses

4. Louis, Henry. Fuel. Sec. 1: Coal, Lignite, and Peat. Resources of the Empire, Ernest Benn, Ltd., London, 1924, pp. 25-107.

5. King, K.Y., and Hung, T.C. Proximate Analysis of Chinese Coals. China Geol. Survey, Sin Yuan Fuel Laboratory, Contrib. 13, 1933. Reprinted from Bull. 21, Geol. Survey of China, 1933.

continued--

Table 12. Analyses of Chinese Coals continued--

6. General Headquarters Supreme Commander for the Allied Powers, Natural Resources Section. Fushun Coal Field, Manchuria. Rept. 68, Tokyo, 1947.

7. Bureau of Mines. Coal analyses series.

8. Office, Chief of Naval Operations. Formosa. Econ. Supp., OPNAV 50E-13, June 1944.

9. Inspection Generale des Mines et de l'Industrie de l'Indochine. L'Industrie mineral en Indochine. Hanoi, 1931, 72 pp.

10. Blondel, F. Indochine Francaise. Les Resources minerales de la France d'outre-mer. I. Le Charbon, Paris, 1933.

Source: U.S. Bureau of Mines, Analyses of Foreign Coals, Bulletin 512 (Washington, D.C., Bureau of Mines, 1952), pp. 4-7.

samples is also quite low, but ash content in many cases can be significantly reduced in coal cleaning and beneficiation plants.

Table 13 is a list of coking coal mines in production in Mainland China, with an estimate of annual production for each mine. Even at the lower end of the range of these estimates, the aggregate is 125 million tons or approximately one-third of total coal production in China.

Present and Potential Production

Current estimates of Chinese coal production place Mainland China among the three largest coal producers in the world, following only the United States and the U.S.S.R. (table 14). The 1970 estimate of 360 million tons of Chinese bituminous, anthracite, and lignite compares favorably with the average 1961-65 and 1964-68 production figures of 272 and 294 million tons per year.1/

Despite the large production, coal is in short supply in Mainland China and is occasionally included in lists of rationed goods. The underlying reason for this is that unlike the U.S.S.R. and the developed countries of the Western world, Mainland China does not have large petroleum and natural gas reserves and has not been importing this type of fuel. Hence coal has to supply the fuel requirements of all sectors of the economy (table 15). Not only is it used extensively for metallurgical and electrical generation purposes, but a large portion of each year's supply is also allocated for use in railroad and inland waterway transportation, small industries, and domestic space-heating.

1/ 1961-1965 average figure derived from K.P. Wang, "The Mineral Resource Base of Communist China," in An Economic Profile of Mainland China, Vol. I, p. 174. 1964-68 figure is from U.S. Department of the Interior, Bureau of Mines, International Coal Trade, vol. 40, no. 4, April 1971, p. 20.

Table 13. Coking Coal Mines in Production in Mainland China

(In millions of metric tons)

Location	Province	Estimated annual production	Connected by rail to port(s) of
Shih-tsui-shan..	Ningsea Hui A.R.	<5	Tientsin
l-p'ing-lang....	Yunnan	<5	Chan Chiang
Shui-ch'eng.....	Kweichow	<5	Chan Chiang
Chungking (area)	Szechwan	<5	Chan Chiang
Chungking (area)	Szechwan	<5	Chan Chiang
Hsi-shan........	Shansi	<5	Tientsin and Tsingtao
Hsien-kang-chen.	Shansi	<5	Tientsin and Tsingtao
Ta-t'ung........	Shansi	10-20	Tientsin
Ping-ting-shan..	Honan	5-10	Lien-yun-chiang
Feng-feng.......	Hopeh	5-10	Lien-yun-chiang and Tsingtao
Hao-pi..........	Honan	<5	Lien-yun-chiang
Ch'ang-chih.....	Shansi	<5	Lien-yun-chiang and Tsingtao
Yang-ch'uan.....	Shansi	5-10	Tsingtao
P'ing-hsiang....	Kiangsi	5-10	Shanghai
Huai-nan........	Anhwei	10-20	Shanghai
Po-shan.........	Shantung	5-10	Tsingtao
Shan-sung-kang..	Kirin	10-20	Dairen
Liao-Yuan.......	Kirin	<5	Dairen
Chi-hsi.........	Heilunkiang	10-20	Dairen
Shuang-ya-shan..	Heilunkiang	5-10	Dairen
Hao-Kang........	Heilunkiang	10-20	Dairen

Source: Communist China Map Folio, page on Fuels and Power.

Table 14. World Anthracite and Bituminous Production: Five Largest Producers by Selected Years

Country and years	Production (thousand m.t.)	Percent of world production
United States		
Average 1964-68	485,414	23.7
1967	508,379	25.1
1968	500,665	24.2
1969	513,436	24.3
1970a/	538,506	24.7
U.S.S.R.		
Average 1964-68	436,900	21.4
1967	451,400	22.2
1968	456,000	22.1
1969	468,000	22.2
1970a/	474,000	21.8
Mainland China		
Average 1964-68	294,000	14.4
1967	250,000	12.3
1968	300,000	14.5
1969	325,000	15.4
1970a/	360,000	16.5
European Economic Community		
Average 1964-68	202,300	9.9
1967	184,600	9.1
1968	175,800	8.5
1969	171,300	8.1
1970	164,600	7.6
United Kingdom		
Average 1964-68	181,264	8.9
1967	174,927	8.6
1968	166,712	8.1
1969	152,962	7.2
1970a/	144,555	6.6

a/ Preliminary. Data were estimated where no statistics were available.

Source: U.S. Department of the Interior, Bureau of Mines, International Coal Trade, vol. 40, no. 4, April 1971, p. 20.

Table 15. Consumption of Coal in Communist China
(In millions of tons)

Item	1952	1957	1960	1965
Industry..................	12.7	37.9	130	70
Metallurgy...............	4.8	12.7	60	30
Including coking coal...	3.2	8.2	30	20
Coal mining..............	1.8	4.2	70	40
Other industry...........	6.1	21.0		
Public utility power stations.................	3.0	11.2	40	30
Transport.................	7.0	10.8	30	20
Railroads................	6.7	9.8	--	--
River and coastal shipping....................	.3	1.0	--	--
Commercial sales..........	35.1	67.7	100	80
Home consumption.........	25.2	56.5	80	60
Other....................	9.9	11.2	20	20
Net domestic sales........	58.0	127.0	300	200
Losses, net changes in stocks, local handicraft consumption from own production, net exports and statistical discrepancy.........	8.5	3.7	125	10
Total production..........	66.5	130.7	425	210

Source: John Ashton, "Development of Electric Energy Resources in Communist China," in An Economic Profile of Mainland China, Vol. I, table 3, p. 305.

To increase the quantity and quality of production to required levels, the Chinese coal industry must somehow overcome the same obstacle which limits the growth of nearly all of Mainland China's major industrial enterprises: insufficient new capital investment. Given adequate levels of new investment in geological exploration, rail transport capacity, cutting, drilling, and loading machines, and conveyor systems, the average level of productivity in this labor-intensive Chinese industry could probably be doubled or even tripled.

Although no recent Chinese statistics are available concerning the average man-day productivity within the coal mining sector, a report published in 1965 indicated that a record level of 2.456 metric tons per man-day had been set at the Shihch-echieh mines in coal-rich Sansi Province where nearly half of Mainland China's estimated coal reserves are concentrated.1/ In contrast, man-day productivity in U.S. underground bituminous operations was approximately 12.45 metric tons per man-day during 1965.2/ Since there is no reason to suspect that the average rate of productivity in Chinese coal extraction has made any outstanding advances in the recent past, it may be assumed that the current national average figure is below 2.5 tons per man-day.

There is reason to believe, however, that given the extent of near-surface deposits already located in Mainland China,3/ an initial injection of large sums of domestic or foreign capital into the coal industry

1/ Productivity figure from K.P. Wang, "The Mineral Industry of Mainland China," in U.S. Department of the Interior, Bureau of Mines, 1965 Minerals Yearbook, Vol. IV, Washington, D.C., 1965, p. 1119. Estimate of Shansi reserves from John Ashton, "Development of Electric Energy Resources in Communist China," in An Economic Profile of Mainland China, Vol. I, p. 303.
2/ Converted to metric equivalent from National Coal Association, Bituminous Coal Facts 1966, Washington, D.C., 1966, p. 77.
3/ See Communist China Map Folio, page on Fuels and Power.

would greatly increase production potential, thus providing the additional quantities needed for domestic industrial expansion and the resumption of foreign coal trade on a greatly increased scale.

Potential Coal Exports to Japan

It is understood that the only major factor which presently prevents the Japanese from importing Chinese coking coal in large quantities is the relatively limited supplies currently available of this grade of coal.1/ An extensive Sino-Japanese technical cooperation program involving the use of Japanese development funds to expand production is a possibility that could alleviate these limitations. Each could benefit enormously from a joint venture of this nature.

Developments of this nature would depend heavily on the concomitant expansion of Mainland China's domestic rail transport facilities which already bottleneck the domestic distribution of fuel and agricultural products. However, as table 13 demonstrates, all of the principal coking coal mines presently in production are linked by rail to adjacent major and secondary ports. With the completion of the proposed Shensi and Szechwan tracks,2/ the vast coal reserves of the northeastern, northern and southern provinces will similarly be accessible by rail from the major port areas.

Whether or not Chinese metallurgical coal could prove qualitatively equal to that of the United States remains to be seen. No definitive conclusions can be drawn from the quality analyses of Chinese coal in table 12, as it gives no indication either of the extent of prior preparation of the samples tested or their coking properties. Similarly, the lack of more recent analytical data from China precludes the

1/ From interview with Joseph Liamari, U.S. Bureau of Mines, Washington, D.C.
2/ Communist China Map Folio, page on Railroads.

possibility of an objective qualitative analysis based upon geological discoveries made since the present regime came into power. Consequently, there is some question as to the desirability of Chinese metallurgical coal relative to those presently imported by the Japanese. Until proven otherwise, however, it may be assumed that some very large reserves of high-quality coking coal do exist in China, that they will be exploited as soon as technology and capital permit, and that they will compete with U.S. coal in the Japanese market and perhaps in other markets.